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# Mosquito News

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# PAPERS AND PROCEEDINGS OF THE 16th ANNUAL MEETING

of the

## AMERICAN MOSQUITO CONTROL ASSOCIATION

Held Jointly with the Northeastern Mosquito Control Association
Boston, Massachusetts, March 27–30, 1960

Part II *

## WATER MANAGEMENT IN MARSH AREAS FOR MOSQUITO CONTROL AND THE CONSERVATION OF WILDLIFE

P. BRUCE BROCKWAY, JR.
*Superintendent, Toledo Area Sanitary District*

Mosquito control groups in the Midwest have not been as actively cooperative with the various wildlife and conservation organizations as those in the East. This could be for a number of reasons, such as lack of opportunity, or perhaps because many of the agencies have not been in existence long enough, and have not made the effort. There is also the possibility that we have been on the defensive instead of the offensive on such projects. I think that the latter reason is the most common one.

Last year the Toledo Area Sanitary District was publicly criticized because we burned off an 80-acre tract of marsh and supposedly killed some rabbits, pheasants and other such forms of wildlife. Later, it was learned that the previously mentioned rabbits had been killed by dogs or other four-footed animals roving this marshland and the burning of the marsh only served to expose the bodies.

This particular marshland has been a mosquito control problem to us for a number of years, mainly because of the pollution flowing into the marshlands from the main watercourse known as Otter Creek. The marsh itself is subject to the water level changes of Lake Erie because it is within a half a mile of the lake and it is connected by Otter Creek.

As the Toledo area receives northeast winds, this area floods; as the winds reverse the water recedes. This wind change normally takes place four to eight times during the normal mosquito breeding season. Therefore, we have a major mosquito problem in this marshland as often as there is a change in the wind direction.

Cattails are the prevalent vegetation and they attain the height of six to eight feet. All these obstacles cause a major problem in controlling *Culex pipiens,* as they lay their eggs under the bent and broken cattails during periods of high water that is polluted.

In 1958, our little Hopto backhoe dug a few short canals in the marshland and our spoil material remained fairly stable in spite of the fact that it was largely organic. In 1959 our dragline cleaned the outlet of Otter Creek and the water in the marsh receded and left a bank edge approximately 18 inches high. During the same

* The Proceedings papers included in this issue comprise the papers that had not been received in form for publication in time for the June number.

summer our backhoe was able to make considerable headway on a canal system within the marsh, and Otter Creek was, to a limited degree, diked off from the marsh itself except during flood stages.

The canal waterways are 20 feet wide and 4 feet deep (Figure 1). This happens to be the approximate size of the canals used by the managed duck marshes along the south Lake Erie shore. As we progressed with our water management equipment into this problem area we were impressed with the possibility of pumping the water down and within the canal banks. Originally these waterways were to be used by our air boat in our larviciding program but as progress was being made on improvement of the canals we could visualize a cooperative effort with the conservation agencies interested in duck management; therefore, the District purchased a 10-inch low head, propeller-type pump. This unit will be mounted on the dike between the marsh and the same watercourse. The intake will be located at the lower end of the canal system and it will discharge into the main Otter Creek watercourse. The cost of the pump was $530.00, but this figure does not include the cost of the engine.

This is the same type of pump used in our local duck marshes and it is designed to pump the water level down and into the canal waterway system within 18 hours of operation. The purpose of the pump is only to lower the water level to a point within the banks of the canal and not to dry out the marsh. By keeping the water within the canal system the area not only can be used by the ducks and other aquatic birds, but also our *Gambusia* minnows will be able to live and reproduce in such numbers that chemical mosquito control may not be necessary.

There is a spirit of cooperation between the state conservation agencies of Ohio and the Toledo Area Sanitary District. During the past year our District

FIG. 1.—Marsh canal under construction

was given the courtesy of a very fine article published in the *Ohio State Conservation Bulletin*. The author gave our District due credit for the consideration that we have given wildlife and he complimented us for our efforts in the biological control of mosquitoes. Therefore, the District is obligated to continue these efforts and it was with this in mind that the District changed its control efforts in the Otter Creek marsh. We propose to work toward cooperative efforts with the duck marsh conservation group because for the proper duck marsh management the water is pumped down during the summer and spring in order to increase vegetation growth. During the fall and winter the water is allowed to rise to the natural levels and, of course, this is the time that mosquitoes are not a problem in this area. We will maintain the banks of the canal in much the same manner as the duck marsh owners recommended and of course we can expect the same vegetation growth results.

Because we will be controlling, our water levels will be much the same as those in the duck marshes and this vegetation will assist in maintaining a solid berm. At the time of the completion of the project, we will dike off Otter Creek from the marshland and we will depend on the clean waters of the adjacent high grounds to feed the clear water into the marsh during fall and winter.

Another opportunity that we have had to cooperate with conservation agencies is on the reduction of pollution of our streams. The Toledo Area Sanitary District does not have legally regulated control of polluted waters, but as we all know, this type of water does invite *Culex pipiens* and this species of mosquito is one of the major mosquito problems in the Toledo area. Therefore, we report pollution problems and offenders to the local and state authorities responsible for the control of water pollution.

With these concrete evidences of cooperation I believe we are on the road to a closer coordination of efforts with the local conservation and naturalist groups. I do not mean to paint a picture that we have been completely at odds with these groups in the past, but there has been a certain feeling of distrust and apprehension toward our organization caused mainly by some misleading information as well as the thought that the Toledo Area Sanitary District might misuse insecticides and the privileges of the Ohio Sanitary District Act.

I am certain that not only will this water management project be a success but it will also serve as a guide for similar future projects in the Toledo area.

# RESIDUAL EFFECTIVENESS OF SOME NEW INSECTICIDES AGAINST ADULTS OF *ANOPHELES QUADRIMACULATUS* SAY

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The application of insecticide residues in buildings has been the principal method of reducing vector populations in malaria eradication programs. Residual treatments have also been widely used by the Armed Forces, as well as by individuals, for protection against mosquito attacks. The chlorinated hydrocarbon insecticides, especially DDT and dieldrin, and BHC to a lesser extent, have been the insecticides of choice, but resistance to these materials is continually spreading and alternate groups of insecticides are needed as substitutes. To fill this need, the residual effectiveness of various organophosphorus compounds and insecticides in other chemical groups is being investigated at various laboratories. Since 1943, when tests were initiated at Orlando, Fla., in cooperation with the Armed Forces to evaluate the residual effectiveness of DDT against anophelines, numerous insecticides have been examined at this laboratory, with emphasis on organophosphorus compounds in recent years.

Within the last year the 19 organophosphorus and carbamate insecticides listed below were tested against *Anopheles quadrimaculatus* Say, in comparison with DDT and malathion standards:

| | |
|---|---|
| Hercules AC–5727 | *m*-isopropylphenyl methylcarbamate |
| Bayer 29493 | *O,O*-dimethyl *O*-(4-methylthio-*m*-tolyl)phosphorothioate |
| Monsanto CP 11223 | 2, 2-dichloro-1-(dimethylphosphinyl)vinylidene dimethyl phosphate |
| American Cyanamid 12008 | *O, O*-diethyl *S*-(isopropylthiomethyl) phosphorodithioate |
| Bayer 24869 | 1-chloromethyl ethyl 2, 2-dichlorovinyl ethyl phosphate |
| Sevin | 1-naphthyl methylcarbamate |
| Methyl Trithion | *S*-(*p*-chlorophenylthio) methyl *O, O*-dimethyl phosphorodithioate |
| Dimethoate | *O, O*-dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate |
| Dibrom | 1, 2-dibromo-2, 2-dichloroethyl dimethyl phosphate |
| Trithion | *S*-(*p*-chlorophenylthio)methyl *O, O*-diethyl phosphorodithioate |
| Phorate | *O, O*-diethyl *S*-(ethylthio) methyl phosphorodithioate |
| Delnav | 2, 3-*p*-dioxanedithiol *S, S*-bis(*O, O*-diethyl phosphorodithioate) and related compounds |
| Dimetilan | 3-methyl-5-pyrazolyl dimethylcarbamate |
| Potasan | *O, O*-diethyl *O*-(4-methylumbelliferone) phosphorothioate |
| Co-Ral | *O*-(3-chloro-4-methylumbelliferone) *O, O*-diethyl phosphorothioate |
| Bayer 22408 | *O, O*-diethyl *O*-naphthalimido phosphorothioate |
| American Cyanamid 12503 | *O,O*-diethyl *O*[2-phenyl-6-(3(2*H*)-pyridazinonyl)] phosphorothioate |
| Dow ET-15 | *O*-methyl *O*-(2, 4, 5-trichlorophenyl)phosphoramidothioate |
| ethyl DDVP | 2, 2-dichlorovinyl diethyl phosphate |

The mosquitoes were from a colony which has developed a high level of resistance to dieldrin in the course of many years of laboratory maintenance. At the time these tests were made the larvae showed about 100-fold resistance, and adult mortality did not exceed 16 percent following a 1-hour exposure on papers treated with 0.8 percent dieldrin, using the World Health Organization standard test kit. The strain is not resistant to DDT.

Nine series of duplicate tests were made, each series consisting of three or four experimental insecticides and a standard. Malathion was used as the standard in series 2 and 4, and DDT in the others. Acetone solutions were sprayed on pine plywood panels at the rate of 100 mg. of active ingredient per square foot. The panels were tested after aging for periods ranging from 1 day to 24 weeks. Enough panels were sprayed with each insecticide to avoid the necessity of using the same panel for two tests. In each test 20 to 40 1- or 2-day-old mosquitoes were exposed under half sections of Petri dishes on the treated panels for periods ranging from 1 to 120 minutes. The insects were then transferred to cylindrical screen cages and provided with a 10 percent honey solution in absorbent cotton pads, and mortality counts were made after 24 hours. The results with the 13 most effective compounds are given in Table 1.

TABLE 1.—Mortality of *Anopheles quadrimaculatus* after exposure to residues of insecticides for various periods. (Average of duplicate tests.)

| Insecticide | Series | Minutes of exposure | Percent mortality on residues aged for— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 day | 1 week | 2 weeks | 4 weeks | 8 weeks | 12 weeks | 16 weeks | 20 weeks | 24 weeks |
| Hercules | 6 | 1 | 100 | 100 | 100 | 100 | 100 | 67 | 20 | 0 | 0 |
| AC-5727 | | 5 | 100 | 100 | 100 | 100 | 100 | 100 | 97 | 71 | 60 |
| | | 15 | — | — | — | — | — | 100 | 100 | 100 | 100 |
| Bayer 29493 | 9 | 5 | 100 | 100 | 100 | 100 | 100 | 50 | 50 | 4 | — |
| | | 15 | 100 | 100 | 100 | 100 | 100 | 97 | 84 | 8 | — |
| | | 30 | — | — | — | 100 | — | 100 | 100 | 65 | — |
| | | 60 | — | — | — | — | — | — | — | 96 | — |
| | | 120 | — | — | — | — | — | — | — | 100 | — |
| Monsanto | 5 | 5 | 100 | 33 | 15 | — | 2 | — | 19 | 4 | — |
| CP 11223 | | 15 | — | 100 | 100 | 56 | 92 | 28 | 30 | 19 | 7 |
| | | 30 | — | — | — | 72 | 100 | 60 | 95 | 56 | 32 |
| | | 60 | — | — | — | 100 | 100 | 100 | 100 | 86 | 100 |
| | | 120 | — | — | — | — | — | — | — | 100 | 100 |
| American | 4 | 5 | 100 | 100 | 12 | 46 | — | — | 1 | 0 | 9 |
| Cyanamid | | 15 | — | — | 15 | 100 | 0 | 11 | 30 | 5 | 11 |
| 12008 | | 30 | — | — | 100 | 100 | 3 | 66 | 98 | 58 | 37 |
| | | 60 | — | — | — | — | 100 | 100 | 100 | 100 | 100 |
| Bayer 24869 | 6 | 5 | 100 | 93 | 26 | — | — | 5 | — | — | — |
| | | 15 | 100 | 100 | 56 | — | — | 50 | 7 | 0 | 10 |
| | | 30 | — | 100 | 12 | — | 64 | 100 | 89 | 75 | 47 |
| | | 60 | — | — | 13 | 40 | 100 | 100 | 100 | 100 | 93 |
| | | 120 | — | — | — | 100 | 100 | 100 | — | — | — |
| Sevin | 4 | 15 | 7 | — | — | — | — | 33 | 36 | 45 | 10 |
| | | 30 | 20 | 36 | 7 | 44 | 15 | 82 | 100 | 90 | 47 |
| | | 60 | 95 | 100 | 31 | 92 | 100 | 100 | 100 | 100 | 100 |
| | | 120 | 100 | 100 | 100 | 100 | 100 | — | — | — | — |
| Methyl Trithion | 5 | 15 | — | — | — | — | — | 26 | 7 | 30 | 18 |
| | | 30 | 17 | — | — | 10 | 30 | 59 | 67 | 86 | 100 |
| | | 60 | 92 | 50 | 30 | 66 | 78 | 100 | 100 | 100 | 100 |
| | | 120 | 100 | 100 | 100 | 97 | 100 | 100 | — | — | — |

TABLE 1.—*(Continued)*

| Insecticide | Series | Minutes of exposure | Percent mortality on residues aged for— 1 day | 1 week | 2 weeks | 4 weeks | 8 weeks | 12 weeks | 16 weeks | 20 weeks | 24 weeks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dimethoate | 2 | 15 | 17 | 31 | 15 | — | — | — | — | 21 | — |
| | | 30 | 37 | 97 | 23 | 27 | 4 | 10 | — | 100 | 54 |
| | | 60 | 87 | 97 | 35 | 75 | 35 | 8 | 50 | 100 | 81 |
| | | 120 | 100 | 100 | 100 | 100 | 96 | 96 | 100 | — | 100 |
| Dibrom | 2 | 5 | 100 | 18 | — | — | — | — | — | — | — |
| | | 15 | — | 78 | 24 | 7 | — | — | — | — | — |
| | | 30 | — | 100 | 92 | 25 | 15 | — | — | — | — |
| | | 60 | — | — | 100 | 100 | 5 | — | — | — | — |
| | | 120 | — | — | — | — | 14 | — | — | — | — |
| Trithion | 5 | 30 | 10 | 6 | — | — | — | — | — | — | — |
| | | 60 | 15 | 47 | 20 | 13 | — | — | — | — | — |
| | | 120 | 100 | 100 | 100 | 100 | 64 | — | — | — | — |
| Phorate | 5 | 5 | 100 | 100 | 95 | — | — | — | — | — | — |
| | | 15 | — | — | 100 | 4 | — | — | — | — | — |
| | | 30 | — | — | — | 8 | — | — | — | — | — |
| | | 60 | — | — | — | 28 | — | — | — | — | — |
| | | 120 | — | — | — | 93 | 68 | — | — | — | — |
| Delnav | 5 | 30 | 11 | — | — | — | — | — | — | — | — |
| | | 60 | 55 | 10 | 15 | 10 | — | — | — | — | — |
| | | 120 | 100 | 86 | 96 | 88 | 61 | — | — | — | — |
| Dimetilan | 2 | 5 | 20 | — | — | — | — | — | — | — | — |
| | | 15 | 13 | — | — | — | — | — | — | — | — |
| | | 30 | 50 | 10 | — | — | — | — | — | — | — |
| | | 60 | 47 | 31 | 0 | — | — | — | — | — | — |
| | | 120 | 100 | 97 | 43 | 22 | — | — | — | — | — |
| DDT | 5 | 5 | 11 | — | — | — | 78 | 93 | 63 | 40 | 53 |
| | | 15 | 36 | 27 | 33 | 39 | 89 | 100 | 83 | 69 | 47 |
| | | 30 | 94 | 86 | 43 | 78 | 100 | 100 | 100 | 97 | 63 |
| | | 60 | 100 | 100 | 100 | 100 | 100 | — | — | — | 100 |
| | 6 | 5 | 17 | 46 | 19 | — | — | 79 | 33 | 71 | 10 |
| | | 15 | 45 | 64 | 41 | — | 70 | 98 | 85 | 92 | 41 |
| | | 30 | 100 | 100 | 42 | 40 | 96 | 100 | 100 | 100 | 65 |
| | | 60 | 100 | 100 | 97 | 100 | 100 | 100 | 100 | — | — |
| | 9 | 5 | 21 | 9 | 73 | 29 | 50 | 29 | 50 | 3 | — |
| | | 15 | 59 | 60 | 100 | 57 | 96 | 78 | 89 | 36 | — |
| | | 30 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 85 | — |
| | | 60 | — | — | — | — | — | — | — | 100 | — |
| Malathion | 2 | 5 | 60 | 33 | 49 | 0 | 64 | 6 | 23 | 0 | 12 |
| | | 15 | 96 | 97 | 93 | 100 | 87 | 90 | 36 | 100 | 45 |
| | | 30 | 100 | 100 | 100 | 100 | 100 | 93 | 100 | 100 | 100 |
| | | 60 | — | — | — | — | — | 100 | 100 | — | — |
| | 4 | 5 | 34 | 27 | 13 | 24 | — | — | 0 | 2 | 7 |
| | | 15 | 88 | 100 | 93 | 63 | 0 | 41 | 92 | 27 | 35 |
| | | 30 | 100 | 100 | 100 | 100 | 100 | 93 | 100 | 97 | 93 |
| | | 60 | — | — | — | — | 100 | 100 | — | 100 | 100 |
| Untreated checks | 2 | 120 | 7 | 3 | 4 | 2 | 4 | 0 | 6 | 6 | 3 |
| | 4 | 120 | 1 | 0 | 0 | 6 | 0 | 2 | 0 | 1 | 8 |
| | 5 | 120 | 0 | 0 | 4 | 2 | 7 | 2 | 3 | 3 | 0 |
| | 6 | 120 | 4 | 6 | 2 | 0 | 1 | 11 | 4 | 0 | 3 |
| | 9 | 120 | 0 | 0 | 0 | 1 | 5 | 4 | 0 | 3 | — |

During the first 24 weeks of aging the malathion standard was slightly superior to the DDT, usually giving 100 percent mortality after an exposure of 30 minutes whereas 60-minute exposures were more frequently required with DDT. Hercules AC–5727 was the most effective compound, giving 97 percent to 100 percent mortality for more than 8 weeks after a 1-minute exposure and for 24 weeks after the 15-minute exposure. Bayer 29493 was superior to both standards for 12 weeks, and Monsanto CP 11223, American Cyanamid 12008, and Bayer 24869 for 1 week, and CP 11223 was equal to DDT for 8 weeks. Sevin gave 100 percent mortality and Methyl Trithion and dimethoate 96 percent to 100 percent, following a 60- or 120-minute exposure for 24 weeks. The remaining insecticides were less effective.

There were wide variations in mortality at the shorter exposure periods, but they became less pronounced at the longer exposures, which may be attributable to greater activity of the mosquitoes on certain days or to fluctuations in the susceptibility or vigor of the mosquitoes from generation to generation.

SUMMARY. In laboratory tests with 19 insecticides as residues on plywood panels at 100 mg. per square foot, Hercules AC–5727 was the most effective, giving 97 percent to 100 percent 24-hour mortality after a 15-minute exposure on panels aged for 24 weeks. Malathion usually gave 100 percent kills after 30-minute exposures, and DDT after 60-minute exposures. Bayer 29493 was superior to malathion and DDT for 16 weeks, and Monsanto CP 11223, American Cyanamid 12008, and Bayer 24869 were superior during the first week. Sevin gave 100 percent kills, and Methyl Trithion and dimethoate 96 percent to 100 percent after 60- or 120-minute exposures. The other compounds were less effective.

# DISPERSAL OF INSECTICIDES FROM JET-PROPELLED AIRCRAFT [1]

DAVID L. HAYDEN [2]

## INTRODUCTION

The Navy's vector control requirement for support of troops in military operations may be accomplished in a number of ways. One of the most useful methods, especially in the early stages of a campaign, is the dispensing of insecticides by aircraft. Dispersal equipment is now being furnished for helicopters, but often these aircraft are not available when needed or are highly vulnerable to attack and therefore their use is limited. Because of this, some other means of widely disseminating insecticides is needed. Jet-propelled aircraft are now provided in quantity in the Navy. A limited number of units capable of dispersing insecticides from jet aircraft are now available. The Disease Vector Control Center at Jacksonville, Florida was assigned the mission of evaluating this equipment.

In 1958 and 1959, tests were conducted by this Center to determine the effectiveness of a liquid insecticide dispersal tank, and in 1959, a dry insecticide disseminator was evaluated. This is apparently the first instance in aviation history of dispersing

[1] The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

[2] Testing and Development Entomologist, U. S. Navy Disease Vector Control Center, U. S. Naval Air Station, Jacksonville 12, Florida.

insecticide materials from jet-propelled aircraft.

### DISPERSAL OF LIQUID INSECTICIDE

1. Equipment. a. The apparatus used for dispersing liquid insecticide materials was a tank fifteen feet long weighing about 1,500 pounds when fully loaded with insecticide. It has a capacity of 85 gallons. The tank can be easily mounted on and removed from an aircraft. High pressure nitrogen, supplied from a reservoir in the tank, provides power to propel the liquid from a central container out through a valve at the rear of the tank. The discharge valve can be adjusted to give flow rates of 100 to 400 gallons per minute. Breakup of the liquid is accomplished by impinging it upon a cone mounted one foot beyond the rear orifice. Electrically operated valves, controlled by the pilot, can govern the flow rate and discharge of the insecticide. A bank of cylinders mounted on a trailer cart is used to fill the nitrogen reservoir in the tank. The nitrogen charging and insecticide filling process can be accomplished in about twenty minutes by a crew of two men.

b. The type of jet aircraft used in these studies was a Navy A4D single engine "Skyhawk." It is a highly versatile single seat delta-winged aircraft with a wing span of 28 feet. Built by the Douglas Company, it is efficient at speeds ranging from 200 to 700 miles per hour. Figure 1 shows this aircraft with the spray tank in operation.

2. Operational tests. Operational tests were conducted to determine the effectiveness of the tank and aircraft in both upwind and crosswind flights. Test stations

FIG. 1.—Aerial Application of Insecticide by a Navy A4D "Skyhawk" Jet. Official Photograph, U.S. Navy

were set up at distances of 25 feet along a 500-foot line for the upwind tests, and along a 1,000-foot line for the crosswind tests.

The following materials were used to evaluate dispersal at designated distances along the test line:

a. Microscope slides coated with 10 percent General Electric "Dri-film SC-87," an oleophobic silicone solution. These slides were used for analysis of droplet size and distribution.

b. Cards impregnated with DuPont "oil-red" dye. "Printflex" cards were used in the initial tests, and were replaced in 1959 by "Kromekote" cards. "Kromekote" cards have superior qualities in retaining droplets below 100 microns. These were used to estimate the gallons deposit rate per acre.

c. House flies caged in screen cylinders; each cage containing 20 adult flies.

d. Standard petri dishes used for direct recovery of the droplets. Fourth instar mosquito larvae (*Culex quinquefasciatus*) were exposed in these dishes in the laboratory to evaluate effective swath width.

e. Accessory equipment consisted of weather measuring instruments, smoke bombs, and weather balloons. A large red arrow about 30 feet in length was used for marking the base or center of the flight line and indicated the flight direction. A radio trailer provided communication with the pilot during flight.

When the test line was established and the evaluation equipment was in place, radio contact was made with the pilot and several practice dry runs were performed over the test area to acquaint the pilot with the proper flight procedure. Meteorological conditions were recorded prior to the flight. The pilot was instructed by radio to commence spraying at an exact time. After each flight, the spray was allowed to settle for ten minutes, providing for maximum recovery of the droplets. Additional runs were repeated in a similar manner as above. Flow rates of 100 to 350 gpm, air speeds of 300 to 550 knots and altitudes of 75 to 200 feet were varied in experiments to determine the most favorable factors for dispersal. Flow rates below 150 gallons per minute were not heavy enough to produce a droplet spectrum which would give satisfactory insect kill. Therefore, the flow was increased to 300 gallons or more and gave a satisfactory deposit in all subsequent tests.

Tests materials were returned to the laboratory where droplet size and spectrum analyses were made. The dyed cards were evaluated for deposit rate. Mortality of house flies was recorded at 24 hours after exposure. Larval mosquito mortality rates were recorded at 24 and 48 hours.

3. Results and discussion. a. Crosswind flights. At flow rates of 300 to 350 gpm, an air speed of 450 knots and an altitude of 100 feet, effective kill was obtained up to 1,000 feet, and in some instances even beyond this distance. Droplet size on the test stations nearest the flight line approached that of a coarse spray (200 microns) and gradually decreased in size to that approximating a heavy mist (100 microns) at stations on the outer edges of the swath (1,000 feet from the flight line). This indicates a desirable droplet spectrum for aerial insecticide spray equipment. Table 1 gives data representative of a typical test flight where these conditions occurred.

b. Upwind flights. Recovery of the spray varied considerably even though flight tests were made in exactly the same manner on the same day at practically the same time. Similar wind conditions existed for all tests, i.e., a steady wind of at least five mph was recorded. The effective swath produced in these tests varied from a minimum of 100 feet to a maximum of 300 feet. Determination of the maximum swath in upwind flights is difficult to obtain even under the most ideal conditions. Sudden and/or small changes in the wind direction will often move the deposit to either side of the test line. Because of the high speed of jet aircraft, the problem is further compounded. It is extremely difficult to direct the aircraft over the center of the test line with accuracy. Data indi-

TABLE 1.—Representative crosswind performance data utilizing a liquid dispersal tank mounted on a Navy A4D jet-propelled aircraft. Air speed 450 knots, altitude 100 feet and flow rate 310 gpm. Temperature at six feet, 74° F. Relative humidity 86 percent, wind speed 1.5 mph.

| Distance from flight line (ft.) | Deposit gallons per/acre (dyed cards) | Mass median diameter (microns) | Frequency median diameter (microns) | House fly mortality (24 hrs.) | Mosquito larva mortality (4th instar) *Culex quinquefasciatus* | |
|---|---|---|---|---|---|---|
| | | | | | 24 hrs. | 48 hrs. |
| | | | | percent | percent | percent |
| 50 | 0.3 | 208 | 199 | 100 | 100 | 100 |
| 75 | — | — | — | — | — | — |
| 100 | 0.2 | — | — | 100 | 95 | 100 |
| 125 | 0.2 | — | — | — | — | — |
| 150 | 0.08 | 133 | 125 | 50 | 100 | 100 |
| 175 | 0.08 | — | — | — | — | — |
| 200 | 0.2 | — | — | 55 | 100 | 100 |
| 225 | 0.2 | — | — | — | — | — |
| 250 | 0.2 | 136 | 128 | 100 | 100 | 100 |
| 275 | 0.2 | — | — | — | — | — |
| 300 | 0.08 | — | — | 100 | 95 | 95 |
| 325 | 0.14 | — | — | — | — | — |
| 350 | 0.1 | 113 | 105 | 95 | 95 | 95 |
| 375 | 0.1 | — | — | — | — | — |
| 400 | 0.15 | 119 | 97 | 80 | — | — |
| 425 | 0.15 | — | — | — | — | — |
| 450 | 0.1 | — | — | 100 | 85 | 95 |
| 475 | 0.02 | — | — | — | — | — |
| 500 | 0.03 | — | — | 100 | 85 | 100 |
| 525 | 0.03 | — | — | — | — | — |
| 550 | 0.03 | 101 | 94 | 90 | 90 | 95 |
| 575 | 0.025 | — | — | — | — | — |
| 600 | 0.01 | — | — | 95 | 90 | 95 |
| 625 | 0.01 | — | — | — | — | — |
| 650 | 0.01 | — | — | — | 70 | 70 |
| 675 | — | — | — | — | — | — |
| 700 | 0.01 | — | — | 65 | 85 | 95 |
| 725 | 0.01 | — | — | — | — | — |
| 750 | 0.01 | 98 | 90 | — | 85 | 100 |
| 775 | 0.03 | — | — | — | — | — |
| 800 | 0.02 | — | — | 95 | 95 | 95 |
| 825 | 0.01 | — | — | — | — | — |
| 850 | 0.01 | 102 | 87 | — | 85 | 90 |
| 875 | 0.01 | — | — | — | — | — |
| 900 | 0.01 | — | — | 80 | 80 | 90 |
| 925 | 0.01 | — | — | — | — | — |
| 950 | 0.01 | — | — | — | 70 | 80 |
| 975 | 0.01 | — | — | — | — | — |
| 1000 | 0.01 | — | — | — | 80 | 100 |
| 1100 | 0.01 | — | — | — | — | — |
| Control | — | — | — | 10 | 0.5 | 2.5 |

cate, however, that the maximum swath width to be expected approximates 200 feet. There is evidence of a deposit pattern resembling a typical bimodal curve. This condition is apparently caused by the wing tip vortices, a phenomenon already known to occur in propeller driven fixed wing and rotary wing type of aircraft. The blast from the jet engine does not appear to have any appreciable effect on the spray deposit pattern. This is because spray is emitted well below the exhaust of

the aircraft. The effects of delta wing design and small wing span, which are characteristic of the A4D, may need further exploration. There is evidence indicating that an increase of air speed tends to decrease the swath width. Although inconclusive results were obtained in upwind tests, it does appear that adequate coverage can be obtained over a distance of 200 feet, even though there may be a tendency towards an overly heavy deposit in the center of the swath.

## Dispersal of Granular Insecticides

1. Equipment. The equipment used for granule dispersal was an experimental model developed by the Navy for dispensing dry materials from jet-propelled aircraft. In its original design, this device was of the same size and configuration as the liquid dispersal tank. An electric motor, activated by the pilot, operates a discharge value for release of the insecticide. Agitation is not used in this tank, because of the free flowing nature of the granules. Flow rate may be varied by interchanging different size openings on the discharge valve. No special deflection plates were provided to disperse the materials. The distribution of the granules is dependent mainly upon the aircraft turbulence.

2. Materials and procedure. A test line of 500 feet in length with stations spaced 25 feet apart was established. Five by six-inch plates, coated with a thin film of common heavy grease with the coated side up were employed at each station in all tests. The granules readily adhere to the greased surface on impaction. In some tests, 4 x 5 x 2 inch plastic containers were used to recover the granules.

The pilot was instructed by radio to fly in the same manner prescribed for the liquid dispersal flights. All test runs were made into the wind, with the exception of one crosswind flight. Attaclay granules, 20/40 mesh unimpregnated, were used in two of the tests. Vermiculite also was employed in two flights, and 30/60 mesh 10 percent DDT-impregnated Attaclay granules were used in one test.

Problems of aligning the aircraft over the target were also encountered in this test series. It appears that shifting winds influence the spread of granules in much the same manner as occurs with droplets.

The test materials were returned to the laboratory where the granules were tabulated on a special illuminated counting chamber. The average number of granules per square centimeter on the entire 5 x 6 glass plate was calculated. The number obtained was then converted into pounds of granules per acre. Vermiculite samples were evaluated in a similar manner.

## Results and Discussion

The results obtained in these tests using granular 20/40 mesh Attaclay show that the maximum swath width produced was 200 feet. This swath was effected at an altitude of 200 feet and an air speed of 200 knots. The mean deposit across this swath was 1.3 pounds of granules per acre. Representative data are shown in Table 2.

TABLE 2.—Representative upwind performance data obtained using a granular disseminator mounted on a Navy A4D jet-propelled aircraft. Air speed 200 knots, altitude 200 feet, flow rate 150 pounds per minute. Temperature 60° F., wind speed 10 mph. A last minute light crosswind shifted the deposit to the right of the flight line

| Distance from center of flight line—feet | Deposit rate pounds of granules per acre |
|---|---|
| 25 | 0.128 |
| 50 | 0.128 |
| 75 | 0.514 |
| 100 | 3.087 |
| 125 | 3.599 |
| 150 | 1.285 |
| 175 | 1.413 |
| 200 | 1.221 |
| 225 | 0.257 |
| Mean Deposit | 1.292 |

At altitudes below 200 feet, the swath width was reduced to less than 125 feet.

In one crosswind test, a swath width of 200 feet was obtained, with a mean deposit of 0.19 pound of granules per acre. This test was also made at an altitude of 200 feet and an air speed of 200 knots. Data recovered in this test series also indicated that increasing the speed of the aircraft tends to decrease the swath width. In trials using vermiculite, the data recovered were inconclusive. However, swaths of 200 feet were obtained.

## CONCLUSIONS

Under present day considerations, it would seem that insecticide dispersal by jet aircraft is very costly and somewhat impractical at least for civilian usage. However, after the importance of military aircraft was established in World War I, many civilian uses for aircraft became apparent. It is therefore not unreasonable to assume that in the future, we may find that jets will be employed for mosquito control or agricultural purposes in place of or in competition with propeller driven craft. There is no question that jet aircraft have promising potentialities for insect control work. However, much research remains to be done in determining the type of jet and dispersal equipment most suitable for a wide range of control applications.

Certainly, for the present at least, jets will be invaluable for use where no propeller-driven craft are available. It is doubtful, however, that jet-carried equipment will be extensively used, except for aerial dispersal of insecticide in support of tactical military operations. There are some instances, however, where they could be usefully employed. Such conditions could exist where mass applications are required such as in disaster or other emergencies, and where spray drift or contamination outside of the target area would not be a hazard.

## SUMMARY

Studies were conducted in 1958 and 1959 to determine the efficacy of dispersing liquid and granular insecticides from jet-propelled aircraft. The type of aircraft used in these studies was a Navy A4D single engine "Skyhawk." The tank for dispensing liquid insecticides uses high pressure nitrogen to propel the liquid through an opening at the rear of the tank. Breakup of the liquid is accomplished by impinging it upon a cone mounted beyond the rear orifice. Flow rates of 100 to 350 gpm, air speeds of 300 to 550 knots and altitudes of 75 to 200 feet were varied in experiments to determine the most favorable factors for dispersal. Crosswind swaths of up to 1,000 feet effective for mosquito larviciding were realized using flow rates of 310 to 350 gpm, an air speed of 450 knots and a spraying height of 100 feet. Dispersal of granular materials was accomplished by using a simple gravity flow system at a constant rate of 150 pounds per minute. Air speeds were varied from 200 to 560 knots and altitudes from 50 to 200 feet in upwind swath width determinations. The maximum upwind swath width obtained using 20/40 mesh Attaclay granules was 200 feet with a mean deposit across the swath of 1.3 pounds of granules per acre. This was accomplished at an altitude of 200 feet and an air speed of 200 knots. At altitudes below 200 feet, the swath width was reduced to less than 125 feet. Increasing the air speed showed a tendency to narrow the swath width. This is believed to be the first instance in aviation history of dispersing insecticide materials from jet-propelled aircraft.

# NEWLY RECOGNIZED *AEDES AEGYPTI* PROBLEMS IN MANILA AND BANGKOK *

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During the rainy season of 1956, an epidemic of "hemorrhagic fever" occurred in children in Manila. At the same time, we were in the area conducting a search for arthropod-borne viruses. Clinical, epidemiologic, and laboratory observations of the epidemic were included in the arthropod-borne virus survey, although the relation of the disease to the arthropod-borne virus group was not recognized at that time. Over 750 cases were hospitalized with about 10 percent case fatality. A number of cases had been seen by pediatricians as early as 1954 and the disease had been named Philippine Hemorrhagic Fever (1).

During the rainy season of 1958, an epidemic of a disease called "hemorrhagic fever" or "mystery disease" occurred in Bangkok. Over 2,500 cases were hospitalized with about 10 percent case fatality. As in Manila, a few cases had been observed annually since 1954, but never in epidemic proportion in Bangkok until 1958. At the height of the epidemic a request for our services was made by the King of Thailand through the International Cooperation Administration. We arrived in Bangkok shortly after the peak of the epidemic and while many cases were still occurring.

Clinical manifestations ranged from a mild febrile disease with a slight bleeding tendency to serious cases associated with extensive hemorrhages in the skin and gastro-intestinal tract, and severe shock (2, 3). Cases occurred principally in children under 5 years of age. Clinically and epidemiologically this disease does not resemble closely epidemic hemorrhagic fever of the type encountered in Korea and Manchuria, Kyasanur forest disease of India or any other hemorrhagic disease heretofore described.

The Philippine survey was conducted from August through October of 1956, in an area of southwestern Luzon extending a distance of approximately 100 miles and including the city of Manila. Over 42,000 adult mosquitoes representing at least 51 species of 8 genera were collected by several methods, including animal-baited stable traps, light traps, sweeping, diurnal and nocturnal biting collections, and diurnal resting station collections. Among the most common species collected in urban areas were *Culex quinquefasciatus* and *Aedes aegypti;* in rural areas, *Culex tritaeniorhynchus, Culex fuscocephalus,* and *Aedes albopictus.*

During the course of the Bangkok survey in September of 1958, over 10,000 adult mosquitoes were collected, principally inside urban dwellings. The predominant species were *Culex quinquefasciatus, Aedes aegypti,* and *Culex tritaeniorhynchus.*

From acute sera of cases diagnosed as Philippine hemorrhagic fever, several viruses were isolated and proved to be strains of 2 new agents which have been named dengue 3 and dengue 4, on the basis of their close immunologic relationship to the classical dengue types 1 and 2 (2). Dengue type 3 was also isolated from a pool of *Aedes aegypti* mosquitoes.

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The investigation was carried out in co-operation with the American Armed Forces, the Philippine Health Department, the School of Hygiene, University of the Philippines, the Philippine National Museum, and the Ministry of Health of Thailand.

This appears to have been the first isolation of a dengue virus from naturally infected wild mosquitoes (2).

From the acute sera of cases of Thai hemorrhagic fever, several agents identified as strains of dengue 2 and chikungunya viruses have been isolated. From Thai *Aedes aegypti* mosquitoes, 3 isolations of dengue 2 have been made (2). Chikungunya virus, previously known from Africa, is believed to be transmitted by *A. aegypti* and possibly other mosquito species.

On the basis of the virus isolations and detailed serological studies, it appears quite certain that the etiology of the Manila epidemic was associated principally with dengue 3 and 4 viruses, while the Thai epidemic was associated principally with dengue 2 and chikungunya viruses. The restricted age distribution of the disease may be partially due to the immunity status of the population in which the older age groups exhibit dengue immunity. The most likely vector in both areas is *Aedes aegypti,* partially corroborated on evidence of the virus isolations as well as epidemiologic evidence. Previous dengue epidemics in these countries have occurred during the same season. No classical dengue outbreaks have been reported in these countries in recent years.

In Manila, the majority of daytime house collections included *Aedes aegypti,* which, on the basis of these collections, was second in frequency only to *Culex quinquefasciatus. Aedes aegypti* was found breeding commonly in a variety of artificial containers inside and outside houses throughout the Manila metropolitan area. *Aedes albopictus,* another proven vector of classical dengue was present in urban areas in comparatively low numbers, but was abundant in rural areas, where *Aedes aegypti* was not found. Hemorrhagic fever occurred only in *Aedes aegypti* infested areas.

In Bangkok, *Aedes aegypti* was collected in the great majority of the houses examined. The exceptions were in the wealthy residential sections including those occupied by Europeans and Americans where *A. aegypti* mosquitoes were less abundant and the case incidence was negligible. As in Manila, *A. aegypti* was second in frequency only to *Culex quinquefasciatus* on the basis of daytime house collections. *Aedes albopictus,* although previously reported for Bangkok, was not collected during this survey. *Aedes aegypti* larvae were commonly found in artificial containers inside and outside houses throughout the city. In the poorer districts of the city, rain water is used extensively and is stored in a variety of containers. Large earthenware jars known as "Shanghai jars" were among the most common sources of *A. aegypti* larvae. Flower vases and water-containing ant barriers inside houses were also commonly infested. In some houses, larvae were purposely kept in open pans as a source of live food for pet fighting fish. An additional source of *A. aegypti* in Bangkok was the bilge water in the many small boats, which harbor a relatively large transient population on the rivers and "klongs" of the city.

Adult *Aedes aegypti* were typically found resting inside houses on hanging clothing, clothes lines, bits of string and wire, picture frames, bed nets, and in piles of clothing, boxes and baskets.

No efforts to control the *Aedes aegypti* mosquito in Manila and Bangkok during or after the epidemic have been made to our knowledge. Although these epidemics caused a great deal of alarm and hysteria since the disease attacked young children with high case fatality rate, malaria control occupied the full attention of the agencies concerned with mosquito control in both areas and perhaps rightly so. In addition, Bangkok in 1958 and in 1959 had devastating epidemics of cholera. With limited finances and trained personnel available in both areas, the problem of *Aedes aegypti* control, although of potential severe consequence, has apparently been assigned a low priority as against more pressing public health problems.

A number of public health officials are skeptical regarding the feasibility of an *Aedes aegypti* control program in view of local conditions and express hope that a

vaccine may be developed which will serve as a substitute for mosquito control. Of this, we are skeptical.

It is interesting to note, however, that in malarious areas in these countries, where residual house spraying has been directed against the malaria vector, the *Aedes aegypti* mosquito cannot be found. Its control in these areas has apparently been a side result of the *Anopheles* control campaign. The urban areas of Manila and Bangkok, however, are not within the malaria zones. Some attention has been given to mosquito control in Bangkok but this is being expended largely in the filling of "klongs" which are a source of mosquito species other than *Aedes aegypti*.

In conclusion, newly recognized severe febrile hemorrhagic diseases of children appeared in epidemic form in Manila and Bangkok in 1956 and 1958, respectively. Philippine hemorrhagic fever has been associated etiologically with dengue 3 and 4 viruses, while Thai hemorrhagic fever has been associated etiologically with dengue 2 and chikungunya viruses. The vector in both cases appears to have been the *Aedes aegypti* mosquito on the basis of virus isolations and epidemiologic considerations. The problem of control of *Aedes aegypti* in these areas is one of relative importance and in comparison to more urgent public health problems appears to have been relegated to a low priority despite the hysteria produced at the time of the epidemics.

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# OBSERVATIONS OF *AEDES TAENIORHYNCHUS* DISPERSAL IN EXTREME SOUTH FLORIDA AND THE EVERGLADES NATIONAL PARK

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## I. INTRODUCTION

### *A. History*

In the early summers of 1951 and of 1953, Southeast Florida was invaded by a large flight of salt-marsh mosquitoes, primarily *Aedes taeniorhynchus*. These flights were of an apparent unprecedented nature in that the counties involved had organized mosquito control districts which claimed that their respective breeding marshes were dry and that the invasion was from an outside source. As a result, the Bureau of Entomology, Florida State Board of Health, began, in 1954, a study of the situation to determine the source of the two invasions.

### *B. Geographical Description*

The area under study was all of the Florida Peninsula, from the Tamiami Trail, southward to Rock Harbor on Key Largo. (Figure 1.) This area is 65 miles wide and 60 miles long, or approximately

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2½ million acres, of which the authors estimate 100 to 200 thousand acres are capable of producing salt-marsh mosquitoes.

### *C. Ecological Description of the Area to be Surveyed*

(1) *Metro Miami and Pine Lands.* In the northeast corner of this area is metropolitan Miami with a population of 800,000 which is rapidly expanding in a southwesterly direction. The outward expansion of the metro area can extend only into the rocky pine lands, due to their higher elevation. These rocky pine lands join Biscayne Bay in the southern part of Miami proper and run approximately 40 miles southwesterly to Florida City and Homestead. They have an average width of 5 to 10 miles.

(2) *East Farming Area and Marsh.* Lying between the pine lands and Biscayne Bay is a farming area and the outer one third is semi-salt marsh.

(3) *Transition Area.* South of the farming area lying along the bay, is a transitional area which is a semi-marsh, fresh to brackish.

(4) *Florida Keys* (Sands, Elliott, Old Rhodes, Key Largo, etc.) These Keys or islands begin 15 miles south of metro Miami and extend 30 miles in a slightly southwesterly direction. Sands Key at the northern end is 9 miles offshore, while the distance from Key Largo to the mainland varies from 2 to 5 miles due to the irregularity of the shoreline. These Keys are of rock formation (Key Largo Limestone) fringed with marsh, the center of which is of higher elevation supporting a tropical hammock or woodland.

(5) *Florida Bay.* A very shallow bay lying between the Florida Keys and the mainland; scattered throughout the bay are hundreds of islands, varying from a fraction of an acre to several hundred acres in size. All of these islands have salt marsh characteristics with practically all of them capable of producing mosquitoes. A typical island is flat with a small wave action dike around the perimeter. Tide in Florida Bay is almost exclusively from wind action, with a total range from a few inches to about 3 feet.

(6) *Cape Sable and the Mainland Shore of Florida Bay.* From Jewfish Creek west across to the western end of Cape Sable there is a band of salt marsh dominated by black mangrove and pickleweed, varying in width from ¼ mile to 3 miles. Lying behind the salt marsh band is a transitional zone of buttonwood and red and white mangrove, changing gradually to a fresh water environment which eventually becomes pure sawgrass. Scattered throughout this transitional zone are numerous brackish and fresh water lakes and ponds, and patches of tropical hammock. The ponds dry up seasonally.

(7) *The Gulf Coast Zone.* This zone extends from Cape Sable northwesterly to the Ten Thousand Islands. It consists of ecological types which represent all of the types of salt marshes found on the east coast of Florida except salt flats. Lying behind this area is a non-typical transitional zone of usually *juncus* and sawgrass.

(8) *Sawgrass Glades.* The central portion of the entire area is a pure stand of sawgrass over rock; it is extremely flat and pocked with small cocoplum-myrtle hammocks commonly known as Everglades Keys. The sawgrass area usually goes under water in June and dries up in early winter.

## II. PROCEDURE

After several trial runs with a thirty-foot boat it was decided to use a seaplane to survey the vast breeding areas. Thirty stations scattered through the breeding area on both coasts were checked twice weekly. At each station an adult landing rate was taken, rain and wind data recorded and larval observations made. Seventy other stations were collected by truck one or more times a week.

Thirty-five New Jersey type light traps using 40-watt bulbs were run *nightly* throughout the summer.

Truck trapping as a means of sampling

FIG. 1.—Southern tip of Florida

adult density was used on this survey in the summers of 1955 and 1956, but was abandoned as it required far too many men and too much time.

On charts 1, 2, and 3 are shown in hour miles (hours times miles) easterly and westerly winds and winds from due south along with the average of the nightly collection of the light traps of the eastern zone (N. Key Largo and coast line of Biscayne Bay); middle zone (Pinelands); and western zone (Krome Avenue westward and eastern edge of sawgrass) for 1956. The wind data in the charts were taken from the U. S. Weather Bureau at Miami International Airport, wind 6 p.m. to 6 a.m. only.

During the summer of 1956 there were four major peaks of the western traps (June 4, July 15, August 8 and August 27). Of the four major peaks, three are associated with periods of west wind, while the fourth (July 15) was associated with a period of west wind, followed by south wind, followed by west wind, in one day succession.

It may also be noted that the two prominent peaks of easterly winds coordinate with the two prominent valleys of light trap collections in all three zones. It should be emphasized that all of the traps referred to as "western traps" are eight miles to fifteen miles from a breeding area, whereas all of the eastern zone

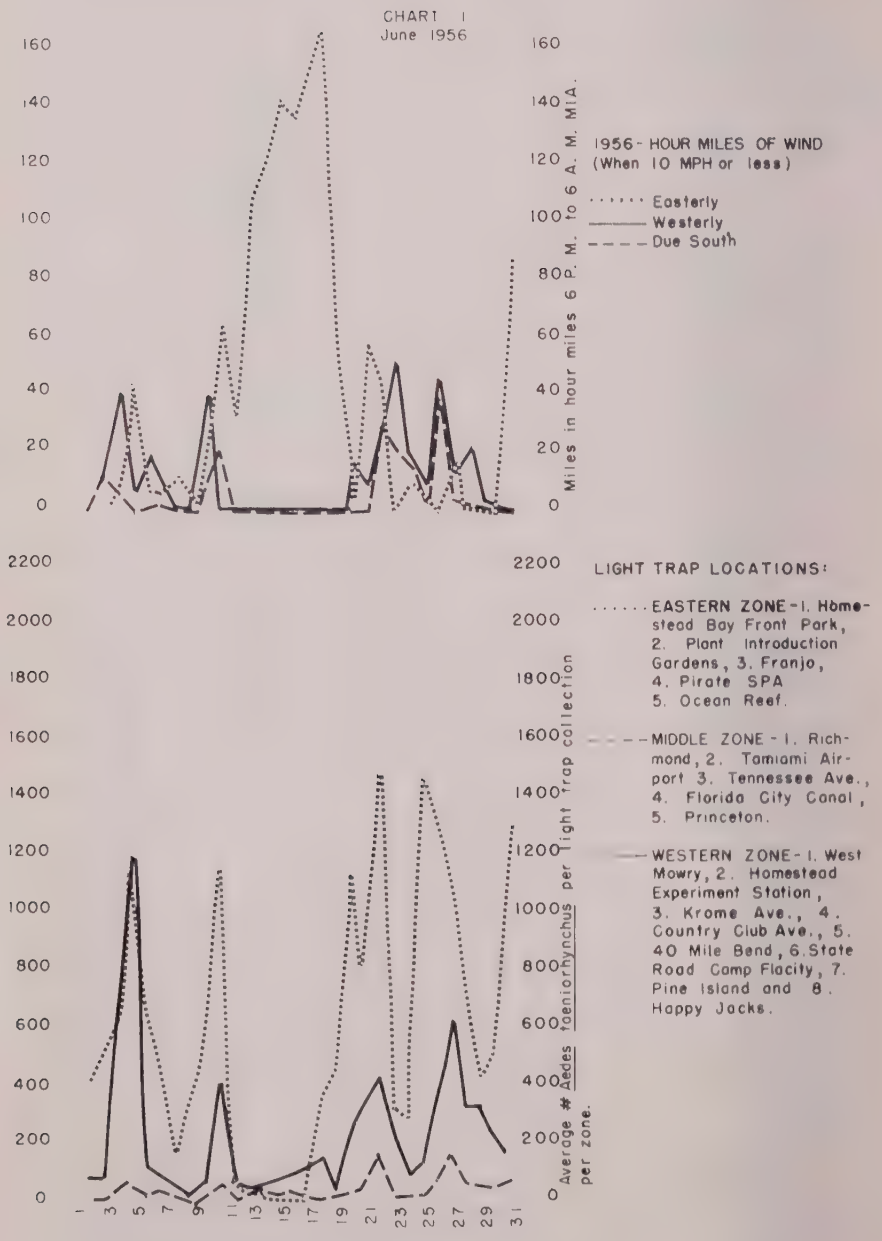
CHART 1
June 1956
160
140
120
100
80
60
40
20
0
Miles in hour miles 6 P. M. to 6 A. M. MIA.
1956 - HOUR MILES OF WIND
(When 10 MPH or less)
Easterly
Westerly
Due South
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Average # Aedes taeniorhynchus per light trap collection per zone.
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
LIGHT TRAP LOCATIONS:
EASTERN ZONE - 1. Homestead Bay Front Park, 2. Plant Introduction Gardens, 3. Franjo, 4. Pirate SPA 5. Ocean Reef.
MIDDLE ZONE - 1. Richmond, 2. Tamiami Airport 3. Tennessee Ave., 4. Florida City Canal, 5. Princeton.
WESTERN ZONE - 1. West Mowry, 2. Homestead Experiment Station, 3. Krome Ave., 4. Country Club Ave., 5. 40 Mile Bend, 6. State Road Camp Flacity, 7. Pine Island and 8. Happy Jacks.

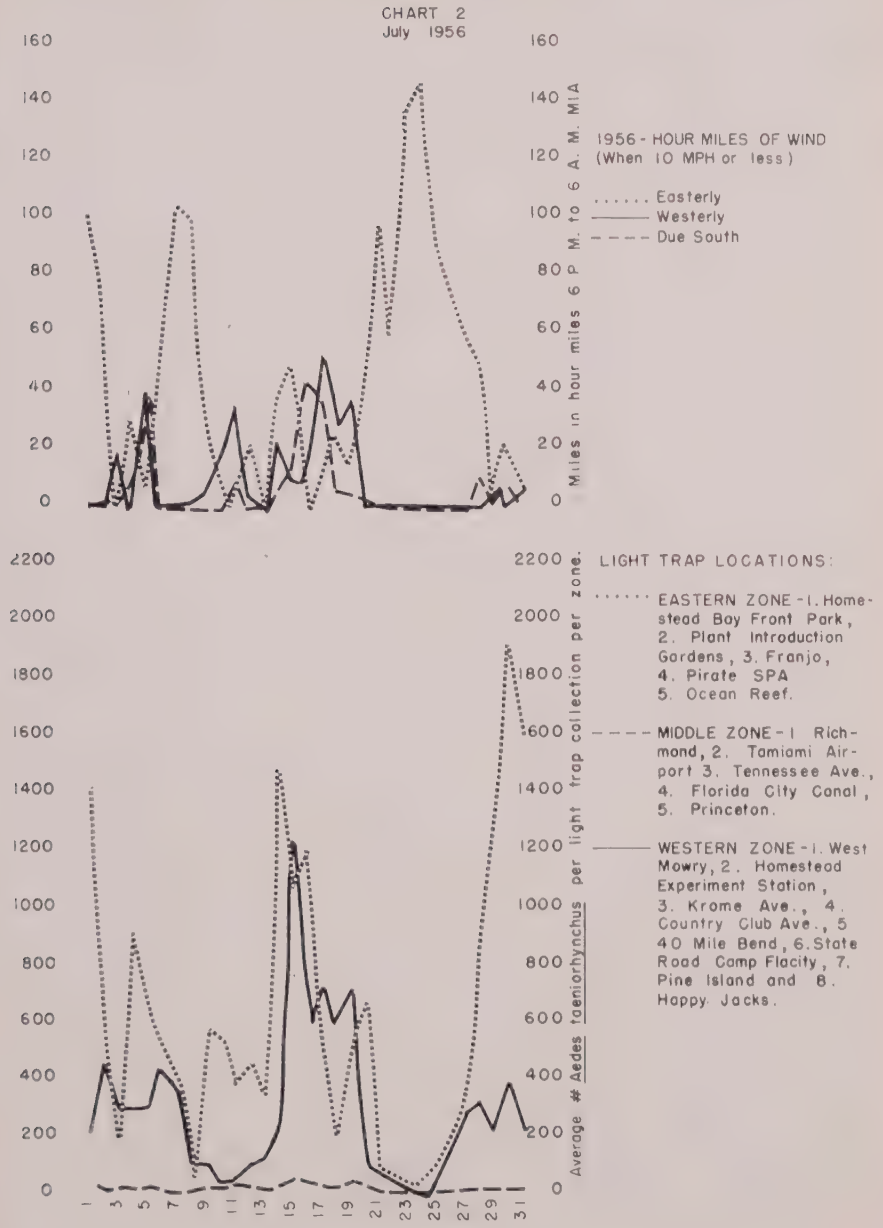
CHART 2
July 1956
160
140
120
100
80
60
40
20
0
Miles in hour miles 6 P. M. to 6 A. M. MIA
1956 - HOUR MILES OF WIND
(When 10 MPH or less)
..... Easterly
——— Westerly
– – – – Due South
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Average # Aedes taeniorhynchus per light trap collection per zone.
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
LIGHT TRAP LOCATIONS:
..... EASTERN ZONE - 1. Homestead Bay Front Park, 2. Plant Introduction Gardens, 3. Franjo, 4. Pirate SPA 5. Ocean Reef.
– – – – MIDDLE ZONE - 1 Richmond, 2. Tamiami Airport 3. Tennessee Ave., 4. Florida City Canal, 5. Princeton.
——— WESTERN ZONE - 1. West Mowry, 2. Homestead Experiment Station, 3. Krome Ave., 4. Country Club Ave., 5 40 Mile Bend, 6. State Road Camp Flacity, 7. Pine Island and 8. Happy Jacks.

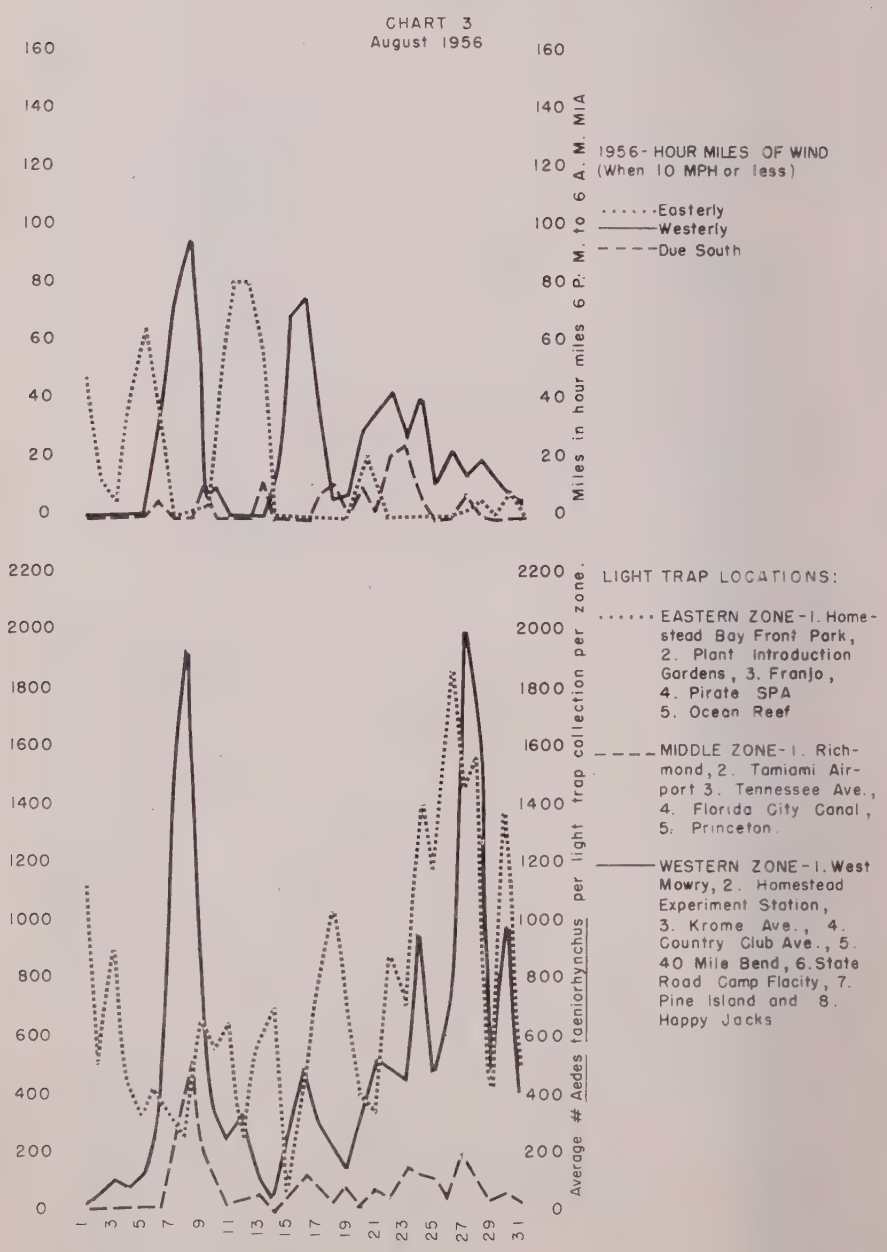
CHART 3
August 1956
160
140
120
100
80
60
40
20
0
Miles in hour miles 6 P. M. to 6 A. M. MIA
1956- HOUR MILES OF WIND
(When 10 MPH or less)
Easterly
Westerly
Due South
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Average # Aedes taeniorhynchus per light trap collection per zone.
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
LIGHT TRAP LOCATIONS:
EASTERN ZONE - 1. Homestead Bay Front Park, 2. Plant Introduction Gardens, 3. Franjo, 4. Pirate SPA 5. Ocean Reef
MIDDLE ZONE - 1. Richmond, 2. Tamiami Airport 3. Tennessee Ave., 4. Florida City Canal, 5. Princeton.
WESTERN ZONE - 1. West Mowry, 2. Homestead Experiment Station, 3. Krome Ave., 4. Country Club Ave., 5. 40 Mile Bend, 6. State Road Camp Flacity, 7. Pine Island and 8. Happy Jacks

traps are within a mile of a breeding area. It might also be emphasized that the two high peaks of the western traps are higher than those of the eastern traps despite their much less advantageous locations.

With reference to the peak of August 8, it is of the utmost importance to know that the seaplane reconnaissance information verifies the following facts:

1. The breeding areas from Sands Key down to Jewfish Creek and across Florida Bay to Flamingo were dry.
2. The rain cans showed little or no rain and adult landing rates were low from July 20 to August 10.

Thus we feel that a sufficient number of mosquitoes to send up all the traps on August 8, could not have come from this area. On the contrary, from Cape Sable northward to Chatham River, rainfall from July 27 to July 30 ranged from one and one-half inches to the south to four inches at Alligator Bay and two and one-quarter inches at nearby Chatham River. Heavy breeding of second instar was observed at Alligator Bay on July 27 and July 30. Landing rates rose from 75 per minute on July 30 at Alligator Bay to 100 plus per minute on August 10 and 150 plus at the Chatham River. These facts, coupled with the period of west wind beginning August 6, lead us to the conclusion that the mosquitoes producing the peak in the traps on August 8, originated in the area between Cape Sable and the Ten Thousand Islands.

We feel that the light trap at Happy Jack's is of particular interest and importance in that it is approximately 18 miles west of Biscayne Blvd. in Miami, and 15 miles from the nearest salt marsh. During the August 6 to 8 invasion mentioned above, it had over 1100 adults on two separate nights, August 6 and 7, and nearly 1100 on August 8, including 40 males on the night of the 7th. It was not uncommon for this trap to have several hundred female *Aedes taeniorhynchus* with an astonishing number of males. Considering that this trap is usually surrounded by many miles of submerged sawgrass after the middle of June and considering that the traps at, or near the east coast had only a fraction as many mosquitoes as Happy Jack's during the August 7 to 8 invasion, it again seems to lead to the conclusion that these mosquitoes came from the heavy breeding areas to the west.

## Conclusions

The authors feel that ample evidence has been presented to draw the conclusion that: When the density of adult mosquitoes in the vast breeding areas between Everglades City and Jewfish Creek is sufficiently high and if at the same time, the wind prevails from the west or southwest steadily and for a long enough period, these mosquitoes will be carried into the populated areas of Dade County, some 30 to 60 miles away.

Inasmuch as Homestead is almost halfway to these breeding areas from Miami, mosquitoes are blown, or move into the Homestead areas much more frequently; moreover, coupled with the fact that east or south wind can also bring mosquitoes into Homestead, this area can expect 50 to 100 nights of annoyance a year from these sources.

In six of the seven years 1951–1957, there was a so-called "Flight" or period of severe annoyance in the Miami area during the first ten days of June.

In nine of the twelve years 1945 to 1956 there were 100 or more hour miles of west wind (nighttime only) during the first ten days of June. During the second ten days of June this occurred in only six of the twelve years and during the third ten days of June it only occurred in four of the twelve years. Therefore, it appears more likely than not, that west wind and mosquito annoyance may be expected during the first ten days of June.

# ARTICLES

## LABORATORY AND FIELD EVALUATION OF NEW INSECTICIDES AGAINST MOSQUITO LARVAE [1]

MIR S. MULLA,[2] LEWIS W. ISAAK,[3] AND HAROLD AXELROD [2]

### INTRODUCTION

Since the advent of chlorinated hydrocarbon insecticides, DDT has been one of the major synthetic insecticides used for mosquito larviciding programs in California. Had it not been for the development in mosquitoes of resistance to chlorinated hydrocarbon insecticides and for the passage of federal laws prohibiting the use of DDT on forage crops, the total amount of DDT employed in mosquito control would have increased due to expanding mosquito control activities. Notwithstanding these factors, the amount of DDT employed for mosquito control in California in 1956 and 1958 was essentially the same for the two years (Anonymous, 1957, 1959) and led other synthetic materials in its total quantity used.

From 1956 to 1958 there was a marked increase in the use of toxaphene. Almost 80 percent of this increase was credited to southern California where DDT usually does not give satisfactory control in the summer months. A few mosquito abatement districts in California started using malathion in 1953 and parathion in 1954. There has been a gradual increase in the use of these materials in succeeding years. By 1958, 90 to 95 percent of the total amount used of these two insecticides was used in the central valley for mosquito control, and, based on total area, parathion was the material most widely used (Anonymous, 1959).

It was in the intensively farmed Sacramento and San Joaquin Valleys that mosquito resistance to insecticides was first confirmed. Here the resistance picture is complicated by intensive use of insecticides for the control of agricultural pests. It was in these areas that resistance of mosquito larvae to DDT and other chlorinated hydrocarbon insecticides was reported earlier (Gjullin and Peters, 1952; Gjullin, 1956; Isaak, 1956*a*). Malathion and parathion became the common substitutes for chlorinated hydrocarbon insecticides. However, in due time studies in the San Joaquin Valley confirmed a 30–35-fold resistance in *Culex tarsalis* to malathion at the LC 90 level (Gjullin and Isaak, 1957).

Within the past two years many control failures have been reported for malathion. Mosquito resistance to this material appears to be becoming widespread, but has not been thoroughly substantiated with published field or laboratory studies. A few mosquito abatement districts have undertaken limited studies of this trend and have confirmed the presence in mosquitoes of a high level of resistance to malathion. The Kern Mosquito Abatement District, for example, has been using malathion since 1953—mostly for urban larviciding. During the 1959 season, however, control of *Culex tarsalis* and *C. quinquefasciatus* by means of malathion was poor.

Parathion is used for mosquito control in agricultural areas where the pests are breeding, but resistance to this material in mosquitoes has also appeared recently. Resistance in *Aedes nigromaculis* larvae to parathion was reported toward the latter

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part of 1958 in one locality in the San Joaquin Valley (Lewallen and Nicholson, 1959). This resistance, so far as is known, has not spread to other parts of the valley.

There is a current tendency (with some hesitation) toward a more widespread use of parathion as a mosquito larvicide in California. The greatest drawback of this material is its high mammalian toxicity, which limits its use in urban or suburban areas where there is concern regarding its toxic hazards. Primarily because of the resistance problem, the current studies were initiated to find substitute materials with insecticidal activity against mosquito larvae superior to that of malathion and approximating that of parathion, but having lower mammalian toxicities than the latter material.

Laboratory Screening. Ten new insecticides were screened against susceptible 4th instar larvae of *Culex quinquefasciatus* Say in the laboratory. Acetone solutions of the various compounds were added to 100 ml. of tap water (pH 8 to 8.5) in one-pint cups to which 25 fourth instar mosquito larvae had been added. Each dosage was replicated 3 times and each material was screened 2 to 3 times on separate days. The larvae were set at 75° to 78° F. and the mortality was recorded 24 hours later.

After preliminary evaluation, materials with activity lower than malathion were eliminated. Only those materials that manifested activity between that of malathion and parathion were screened critically in the laboratory. A chlorinated hydrocarbon compound SD-4402 (1,3,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanophthalan) indicated the highest activity against the larvae (Figure 1). Bayer 29493 (*O,O*-dimethyl *O*-3-methyl-4-methylthiophenyl phosphorothioate), Bayer 34042, and Dicapthon (American Cyanamid 4124) followed in order of decreasing activity. Experimental Nematocide (EN) 18133 (*O,O*-diethyl *O*-2-pyrazinyl phosphorothioate) also indicated appreciable activity. The remaining materials—Bayer 22408 (*O,O*-diethyl *O*-naphthaloximido phosphorothioate), Ethyl Guthion, AC-5727 (m-isopropylphenyl *N*-methylcarbamate), Bayer 25141 (*O,O*-diethyl *O*-*p*-methylsulfinylphenyl phosphorothioate), and Methyl Trithion (*O,O*-dimethyl *S*-*p*-chlorophenylthiomethyl phosphorodithioate)—were superior in activity to malathion but were not as efficient as the other four organophosphates (figure 1). The regression lines of Bayer 29493 and EN 18133 are rather steep and these materials hold promise for mosquito control. Dicapthon, although indicating greater activity than that of malathion in laboratory screening, did not prove as effective as malathion against *Aedes nigromaculis* in the field (Isaak, 1956*b*).

It is generally accepted among workers in California that *Culex* mosquitoes are relatively harder to kill than the other mosquito species. A toxicant that proves effective against *C. tarsalis* or *C. quinquefasciatus* will generally prove more effective against *Aedes* and *Anopheles* mosquitoes. For this reason the laboratory and field evaluation tests have been directed against the two *Culex* species.

## Field Trials

Of the ten new materials showing activity greater than that of malathion in the laboratory, seven were evaluated in the field. Dicapthon was not evaluated because of its poor field performance (Isaak, 1956*b*). Compound GC-3583 [diethyl-1-(2,5-dichlorophenyl)-2-chlorovinyl phosphate] was evaluated in the field but not in the laboratory.

The materials under investigation were evaluated in different types of niches and habitats where mosquitoes breed. These consisted of irrigated pastures, a duck club, a duck club slough, and a river bottom. The water depth in the pastures and the duck club varied anywhere from 2 to 6 inches. Greater water depths were encountered in the plots established in the duck club slough and the river bottom.

Plot size was either 1/16 acre or 1/32 acre. The sprays were applied at the rate of 8 gallons per acre with hand sprayers yielding maximum pressure of 30 psi. Mosquito larval count was obtained by

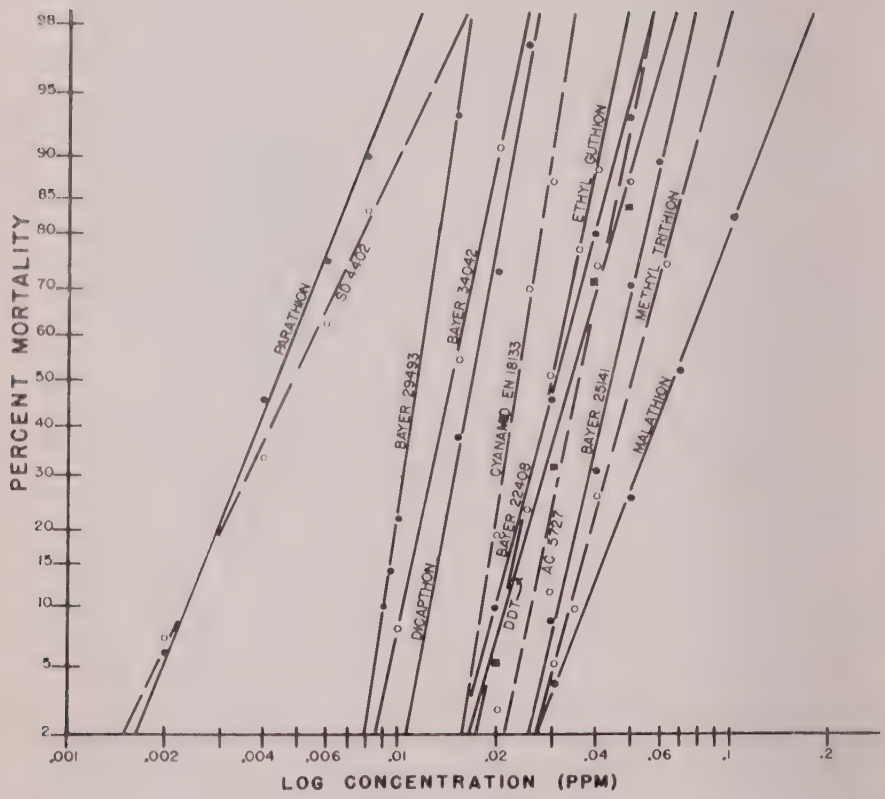


FIG. 1. Dosage mortality lines of ten new insecticides in laboratory screenings against susceptible 4th instar larvae of *Culex quinquefasciatus* Say. Parathion, DDT, and malathion are included for the purpose of comparison.

dippings. Ten to twelve dips were taken per plot, both before and 24 hours after treatment. Only 4th instar larvae of *Culex tarsalis* were recorded.

PASTURE TRIALS. Six new materials and malathion were evaluated in two pastures where emergent vegetation covered 10 to 30 percent of the total area. Because of this variable some differences were observed in the results. However, the results with the various dosages of a material indicated the range of activity of the materials tested.

In the first pasture, Methyl Trithion, Bayer 29493, EN 18133, and malathion were evaluated (Table 1). Bayer 29493 proved to be the most effective material, followed by EN 18133. The latter material did not yield as good results at the highest dosage (0.1 pound per acre) as at the two lower dosages. Methyl Trithion proved effective at dosages of 0.2 and 0.5 pound per acre. This material probably has the same range of activity as malathion against *C. tarsalis*.

In the second pasture, AC-5727, Bayer 25141, Bayer 22408 and malathion were evaluated (Table 2). The population in this pasture was reported in 1955 to have a 75-fold resistance to DDT at the LC 50 level (Isaak, 1955). In this test Bayer 25141 was the only material that man-

TABLE 1.—Field trials with organophosphorous insecticides against *Culex tarsalis* larvae (Baby Pony Pasture, Wasco, California) [a]

| Insecticide and formulation | Dosage, pounds of toxicant/acre | Avg. no. larvae/dip | | Percent of control |
|---|---|---|---|---|
| | | Pre-treatment | Post-treatment | |
| Methyl Trithion EC 4 | 0.100 | 12 | 2.0 | 83 |
| | 0.200 | 8 | 0.0 | 100 |
| | 0.500 | 13 | 0.9 | 93 |
| Bayer 29493 EC 2 | 0.025 | 19 | 4.0 | 79 |
| | 0.050 | 12 | 0.0 | 100 |
| | 0.100 | 2 | 0.0 | 100 |
| EN 18133 EC 4 | 0.025 | 27 | 1.4 | 95 |
| | 0.050 | 10 | 0.4 | 96 |
| | 0.100 | 10 | 2.3 | 77 |
| Malathion EC 5 | 0.200 | 16 | 0.7 | 96 |
| | 0.400 | 10 | 0.2 | 98 |

[a] Plot size 1/16 acre. Water temperature 75°–78° F. during the day.

TABLE 2.—Field evaluation of 4 insecticides against *Culex tarsalis* larvae (Bloomfield pasture, Bakersfield, California) [a]

| Insecticide and formulation | Dosage, pounds of toxicant/acre | Avg. no. larvae/dip | | Percent of control |
|---|---|---|---|---|
| | | Pre-treatment | Post-treatment | |
| AC–5727 EC 1.1 | 0.02 | 9.4 | 19.4 | 0.0 |
| | 0.04 | 11.8 | 11.8 | 0.0 |
| | 0.10 | 9.0 | 7.5 | 16.7 |
| Bayer 25141 EC 2 | 0.02 | 7.8 | 4.2 | 46.7 |
| | 0.04 | 14.8 | 4.8 | 67.6 |
| | 0.10 | 9.4 | 0.0 | 100.0 |
| Bayer 22408 EC 2 | 0.02 | 6.2 | 2.4 | 61.3 |
| | 0.04 | 9.4 | 17.3 | 0.0 |
| | 0.10 | 7.1 | 12.2 | 0.0 |
| Malathion EC 4 | 0.02 | 12.6 | 20.5 | 0.0 |
| | 0.05 | 6.3 | 10.8 | 0.0 |

[a] Plot size 1/32 acre.

ifested a high degree of activity against the larvae at the 0.1 pound per acre dosage. This material, although showing less activity in the laboratory than AC-5727 and Bayer 22408, proved superior to these two in the field. None of the other materials manifested any high degree of activity at the administered dosages.

DUCK CLUB TRIALS. Compounds SD-4402, GC-3583 and Bayer 22408 were evaluated in a duck club covered with a considerable amount of emergent vegetation (Table 3). Bayer 22408 was administered at higher dosages than in the previous test in the pasture and proved ineffective again at the applied dosages. SD-4402 proved to be highly effective and GC-3583 showed greater activity only at the 0.2 and 0.3 pound per acre rates. Gross observations on the activity of these materials against predaceous insects were also made. SD-4402 resulted in greatest mortality, and at the highest dosage proved toxic to frogs. On the other hand, slight damage to predaceous and scavenger insects was observed at the two highest and most effective dosages of GC-3583. Similarly, Bayer 22408 proved harmless to aquatic predators and scavengers, but proved highly lethal to adult Ephydrid-like (probably *Hydrellia* sp.) flies hovering over the treated water.

In a slough where water depth averaged about 2 feet, Bayer 22408 was again eval-

TABLE 3.—Investigations with 3 insecticides against *Culex tarsalis* larvae (Auree Duck Club, Gun Club Road, Wasco, California) [a]

| Insecticide and formulation | Dosage, pounds of toxicant/acre | Avg. no. larvae/dip | | Percent of control |
|---|---|---|---|---|
| | | Pre-treatment | Post-treatment | |
| SD–4402 EC 1.25 [b] | 0.05 | 4.5 | 0.4 | 91 |
| | 0.10 | 5.0 | 0.1 | 98 |
| | 0.20 | 4.6 | 0.0 | 100 |
| GC–3583 EC 4 | 0.05 | 4.9 | 3.5 | 28 |
| | 0.10 | 2.3 | 0.9 | 61 |
| | 0.20 [c] | 4.6 | 0.2 | 95 |
| | 0.30 [c] | 1.6 | 0.0 | 100 |
| Bayer 22408 EC 2 [d] | 0.05 | 4.5 | 6.1 | 0 |
| | 0.10 | 3.4 | 0.7 | 79 |
| | 0.20 | 5.5 | 3.3 | 40 |

[a] Plot size 1/32 acre. Water depth varied from 2 to 6 inches with medium plant cover.
[b] May-fly naiads and scavenger beetle larvae found dead. Sick frogs seen in plot treated with the highest dosage. Mosquito pupae alive at all dosages.
[c] Predators such as backswimmers and diving beetles observed to be alive at these dosages.
[d] Diving beetles and second stage mosquito larvae found alive. Large number of Ephydrid-like flies hovering over the water seen dead.

TABLE 4. Field trials with Bayer 22408 and AC–5727 against *Culex tarsalis* larvae (Tulare Duck Club slough, Garcess Highway, Delano, California) [a]

| Insecticide and formulation | Dosage, pounds of toxicant/acre | Avg. no. larvae/dip | | Percent of control |
|---|---|---|---|---|
| | | Pre-treatment | Post-treatment | |
| Bayer 22408 EC 2 | 0.1 | 3.1 | 0.9 | 71 [b] |
| | 0.2 | 11.9 | 2.6 | 78 [b] |
| | 0.3 | 7.4 | 2.0 | 73 [b] |
| AC–5727 EC 1.1 | 0.1 | 13.6 | 3.2 | 77 [c] |
| | 0.2 | 6.3 | 0.5 | 92 [d] |
| | 0.3 | 9.1 | 0.4 | 96 [d] |

[a] Plot size 1/32 acre. Water depth ranged from a few inches to 3 feet.
[b] Second stage larvae also alive, indicating material ineffective at these dosages.
[c] Young larvae (2nd and 3rd) dead. Fourth stage instars only ones observed alive. Rat-tail maggots alive.
[d] Rat-tail maggots dead.

uated but at still higher dosages (Table 4). It proved to be ineffective under the test conditions, and even young instar larvae (second) of mosquitoes were not touched by the higher dosages of this material. AC-5727, on the other hand, proved to be effective at the highest two dosages. This material, however, proved lethal to predaceous rat-tail maggots at the effective dosages.

RIVER BOTTOM TRIALS. The plots in the river bottom were diked to avoid water flow and diffusion of toxicant from one plot to another. Compound SD-4402 was evaluated at three dosages and it proved highly effective even at the lowest dosage of 0.05 pound per acre (Table 5). This material at the lowest dosage proved harmless to frogs but killed *Gambusia* fish. At the highest two dosages (0.1 and 0.2 pound per acre) this material resulted in complete mortality of frogs.

It is important to note that certain materials investigated here at the effective dosages against mosquito larvae are harmful to predators and scavengers living together with the pests. Certain other materials, on the other hand, are quite harmless to such organisms at the effective

TABLE 5.—Control of *Culex tarsalis* with SD–4402 sprays in river bottom (Kern River, Oildale, California) [a]

| Dosage, pounds of toxicant/acre | Avg. no. larvae/dip | | Percent of Control |
|---|---|---|---|
| | Pre-treatment | Post-treatment | |
| 0.05 [b] | 12 | 0 | 100 |
| 0.10 [c] | 6 | 0 | 100 |
| 0.20 [c] | 8 | 0 | 100 |

[a] Plot size 1/32 acre arranged in Kern River bottom; water depth 2 feet. No emergent or submerged vegetation except some algal growth on surface.

[b] Frogs alive but *Gambusia* fish all dead. No mortality of mosquito pupae observed.

[c] All frogs dead in these treatments. No fish observed either before or after treatments.

dosages. Emphasis on selective materials in mosquito control has been largely overlooked and future investigations should arrive at an integrated control of mosquito pests. This subject has gained emphasis in the control programs of agricultural pests.

ACKNOWLEDGMENTS

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# SOME FACTORS REGULATING THE EFFECTIVENESS OF GRANULAR INSECTICIDES IN MOSQUITO CONTROL[1]

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Granular formulations of insecticides have an important place in the control programs instituted against certain terrestrial and aquatic human and animal insect pests. Such formulations have been employed in experimental control trials against mosquito larvae breeding in rice fields (Whitehead 1951). Their effectiveness was demonstrated against bottom-feeding larvae of *Mansonia* spp. which could not be controlled by spray applications (Chapman 1955). BHC and dieldrin granules were successfully employed against sand fly larvae (LaBrecque & Goulding 1954).

Comparative trials were made using 10, 20 and 35 percent DDT on attapulgite granules and sprays, both applied to soil in the laboratory against *Hippelates collusor* (Tsnd.). The initial effectiveness and the effectiveness after three months' storage of the soil treated with the granules were found to be lower than with the soil treated with the sprays (Mulla 1960). In addition, the effectiveness of the granular formulations decreased as the concentration of DDT increased. The poor performance of the granular formulations could be attributed to either slow release of the toxicant from the pellets or poor distribution of the toxicant in the soil.

Comparative performance data on the effectiveness of various types of granular insecticides against mosquito larvae in the field are lacking. These formulations, although having several advantages over sprays (Mulla & Axelrod 1959), have not been considered in large-scale mosquito-larviciding programs until recently. This lag in the general use of granular insecticides in mosquito control has been attributed to the lack of a formulation that releases the toxicant rapidly. A survey of commercial granular parathion and malathion formulated for mosquito control in California substantiated this lack (Mulla & Axelrod 1959). Some of the formulations released the toxicant slowly; others released the toxicant almost exclusively at the bottom of a water column.

The erratic results obtained with the impregnated type of granular insecticides were to be expected in view of recent information about the role played by the petroleum solvents in impregnation (Mulla & Axelrod 1960). Type and mesh size of the carrier pellets, the kind and concentration of the insecticide, as well as the kind and concentration of the solvent in the granular formulation are expected to influence the speed of release of the toxicant from the granular particles. Some of these aspects of granular formulations of parathion are discussed below.

## METHODS AND MATERIALS

The granular formulations were prepared and evaluated in the laboratory as discussed by Mulla and Axelrod (1960). The solvents were used at a concentration of 10 percent based on the weight of the finished product. Attapulgite granules (Floridin Company, Tallahassee, Florida) were used in all the tests. The prepared granules were dropped into a gallon mayonnaise jar containing 3500 ml. of tap water (pH 8–8.5). The height of the water column in the jar was 8.25 inches. At intervals of 8, 24, 48 and 72 hours, 5 to 10 ml. of water were aspirated from both the top and the bottom (1 inch above the granules) of the jar and composited for further dilution. The details of the initial concentration of parathion in the jar and final concentration in 100 ml. of water in

[1] Paper No. 1213, University of California Citrus Experiment Station, Riverside, California. The assistance of Harold Axelrod in these studies is greatly appreciated.

the pint-size paper cup (replicated three times) to which 25 fourth instar larvae of *Culex quinquefasciatus* Say were added, are included in the tables. Since temperature has a profound effect on the speed of release of a toxicant (Mulla & Axelrod 1960a), the water treated with the granules was maintained at 85° F. The mosquito larvae during the exposure period to the toxicant were kept at 75° to 78° F. and the mortality was read 24 hours after start of the exposure period. The extent of mortality was an indication of the magnitude of release and the percent release was calculated from the observed mortality of larvae in reference to a dosage-mortality line established for parathion against the larvae.

## Results and Discussion

Petroleum Solvents. In the preparation of granular formulations, it is usually desirable to impregnate the granules with the toxicant by means of an organic solvent. Uniform and more efficient formulations are obtained by this method than by simply impregnating the granules with the liquid toxicant. Petroleum solvents are usually cheaper and safer to use for this purpose than other kinds of solvents. Because of the availability of a large number of these solvents, it is difficult to select one that is suitable for a particular type of granular formulation. Using a solvent without knowing its role in granular insecticides could lead to formulations of poor performance.

The release of parathion into water from attapulgite granules was observed to be greatly affected by the solvent used for impregnation (Table 1). After 48 hours certain solvents resulted in slow release of parathion into the water; others resulted in rapid release. Formulations prepared with AR-60, Panasol AN-3, Cyclo-Sol 68W, AR-50, Aromatic Solvent 42, AR-55 and Panasol AN-1 released parathion very slowly. On the other hand, solvents such as Panasol RX-3, AR-35, Panasol RX-4, Cyclo-Sol 27 and Cyclo-Sol 37 released the toxicant much faster. Release of parathion from formulations prepared with AR-60, AR-55, and AR-50 would have remained undetected if the formulations had been tested at 0.02 p.p.m. in the cups.

From the physical properties of these solvents (see Table 1) it is obvious that the extent and speed of release of parathion from the granules is related to these properties of the solvents. Solvents characterized by higher flash points, higher initial and maximum boiling points, and wider distillation ranges released the toxicant

TABLE 1.—The relationship between some physical properties of petroleum solvents and the efficiency of 2 percent parathion granules (30/60 AA-LVM attapulgite) [a]

| Solvent and source | Flash point (° F.) | Initial boil. point (° F.) | Maximum boil. point (° F.) | Distill. interval (° F.) | Percent release into water at 48 hours |
|---|---|---|---|---|---|
| AR–60 (Velsicol) [b] | 220 | 460 | 560 | 100 | 7 |
| Panasol AN–3 (Amoco) | 220 | 450 | 534 | 84 | 9 |
| Cyclo-Sol 68W (Shell) | 151 | 364 | 418 | 54 | 13 |
| AR–50 (Velsicol) [b] | 200 | 415 | 550 | 135 | 14 |
| Aromatic Sol. 42 (Shell) | 164 | 383 | 498 | 115 | 17 |
| AR–55 (Velsicol) [b] | 180 | 390 | 550 | 160 | 18 |
| Panasol AN–1 (Amoco) | 165 | 400 | 494 | 94 | 20 |
| Panasol RX–3 (Amoco) | 81 | 276 | 360 | 84 | 58 |
| AR–35 (Velsicol) | <40 | 214 | 278 | 64 | 60+ |
| Panasol RX–4 (Amoco) | 81 | 282 | 320 | 38 | 60+ |
| Cyclo-Sol 27 (Shell) | 35 | 212 | 229 | 17 | 60+ |
| Cyclo-Sol 37 (Shell) | 75 | 269 | 282 | 13 | 60+ |

[a] The theoretical concentration of parathion in the gallon jar was adjusted to 5 p.p.m. All formulations were tested fresh.

[b] Tested at 0.05 p.p.m. in cups. All others tested at 0.02 p.p.m.

slower than those characterized by lower values for these properties. It thus becomes obvious that an inverse relationship exists between the magnitude of release of parathion (after 48 hours in this case) and the values of these physical properties of the solvents.

The flash points and initial boiling points of Panasol RX-3 and RX-4 are essentially the same, but the maximum boiling point of the former solvent is higher. This difference results in a wider range of distillation for RX-3 than for RX-4, and, therefore, a slower release of the toxicant by RX-3 than by RX-4.

Selection of a solvent for preparing a granular formulation will depend on whether a fast- or slow-releasing formulation is required, and on the economics of the situation. Both fast- and slow-releasing materials have places in mosquito control, and the decision to use one or the other should be determined by the available information concerning specific conditions.

Safety is a factor that is also involved. Solvents with low flash points constitute fire hazards and should be stored and handled as dictated by safety rules and regulations.

RATE OF APPLICATION. Increasing the rate of application of the toxicant means an increase in the number of granular particles per unit area or per unit volume of the treated water. Variation in number of granular particles per unit area or per unit volume within limits influences the release of parathion to a great extent. At the 2 and 5 p.p.m. concentrations (parathion is soluble up to 20 p.p.m. at the temperature used here) parathion release was proportionately lower than at the 0.5 and 1 p.p.m. concentrations (Table 2). Also at the 0.5 p.p.m. concentration the percent release (after 8 hours) was greater than the release at the 1 p.p.m. concentrations for both solvents. After 24 hours the AR-60 formulation released parathion faster at the 0.5 p.p.m. than at the 1 p.p.m. concentration.

An inverse relationship between proportionate release of parathion and its concentration in the treated water was observed for the 8-hour interval for both formulations prepared with Chevron Light Solvent (Standard Oil Company of California) and AR-60. Formulation prepared with Chevron Light Solvent released the insecticide faster than the formulation prepared with AR-60. After 48 hours the proportionate release for the 0.5 and 1 p.p.m. concentrations was the same for the formulation prepared with Chevron Light Solvent. Similarly, the release for the 0.5 and 1 p.p.m. concentrations was the same for

TABLE 2.—Release of toxicant from 2 percent parathion granules (30/60 AA-LVM attapulgite) applied to water at various rates

| Solvent | Toxicant rate [a] (p.p.m.) | Avg. percent mortality of larvae at intervals (hours) 8 | 24 | 48 | Percent release at 48 hours |
|---|---|---|---|---|---|
| Chevron Light Solvent [b] | 5.0 | 0 | 33 | 59 | 39 |
| | 2.0 | 3 | 81 | 87 | 60 |
| | 1.0 | 4 | 97 | 98 | 96 |
| | 0.5 | 28 | 97 | 98 | 96 |
| AR-60 [c] | 5.0 | 3 | 0 | 61 | 12 |
| | 2.0 | 4 | 0 | 95 | 24 |
| | 1.0 | 8 | 8 | 100 | 30–35 |
| | 0.5 | 19 | 25 | 100 | 30–35 |

[a] The rate applies to the gallon jar containing 3500 ml. of water.
[b] The formulation was 4 months old, and tested at 0.0125 p.p.m. final theoretical concentration.
[c] The formulation was 7 months old, and tested at 0.04 p.p.m. final theoretical concentration in the cups.

the formulation prepared with AR-60 solvent.

In mosquito control, under normal conditions, parathion is usually applied at rates lower than 0.1 p.p.m. Therefore, the proportionate release from granular materials will more likely be higher than the highest releases (prior to total release) obtained here at the 0.5 p.p.m. concentrations. Nevertheless the relationship between rate of application and speed of release shows important trends. This trend might have more practicable applications for other types of granular formulations.

TOXICANT CONCENTRATION. Toxicant concentration in a granular formulation has economic implications in the use of granular insecticides. Increasing the toxicant in a formulation will decrease the cost per unit of the formulated toxicant. Cost factors and performance of formulations of various concentrations have to be weighed before making a decision to use any one concentration.

The relationship between the toxicant concentration in a granular formulation and its release from the material is not a simple one. The picture is complicated by the type of solvent used for impregnation. Formulations prepared with a highly volatile solvent (Chevron Light Solvent) indicated an inverse relationship between concentration of the toxicant and release of the toxicant from the granules (Table 3). But a low-volatile solvent (AR-60) produced different results that indicated a direct relationship between concentration of parathion in the formulations and release of it from the granules. The overall efficiency of all concentrations prepared with the high-volatile solvent was greater than that of the formulations prepared with the low-volatile solvent. The 5- and 10-percent formulations prepared with Chevron Light Solvent released the toxicant slower at all intervals than the 1- and 2-percent formulations. On the other hand, the 5- (except for the 8-hour interval) and 10-percent formulations prepared with AR-60 solvent gave faster release at all intervals than the 1- and 2-percent formulations.

Further studies on the effect of concentration of parathion on its release were carried on using various mesh sizes of granules and employing Chevron Light Solvent for impregnation. An inverse relationship between concentration of parathion used and its release was also observed

TABLE 3.—The effect of concentration of toxicant in formulations on the efficiency of parathion granules (30/60 AA-LVM attapulgite) [a]

| Solvent | Percent parathion conc. | Avg. percent mortality of larvae at intervals (hours) | | | |
|---|---|---|---|---|---|
| | | 8 | 24 | 48 [b] | 72 |
| Chevron Light Solvent [c] | 10 | 0 | 21 | 23 | 48 |
| | 5 | 0 | 97 | 98 | 98 |
| | 2 | 53 | 100 | 100 | 100 |
| | 1 | 73 | 100 | 100 | 100 |
| AR-60 [d] | 10 | 51 | 48 | 67 | 100 |
| | 5 | 0 | 5 | 39 | 81 |
| | 2 | 0 | 0 | 4 | 21 |
| | 1 | 0 | 3 | 0 | 7 |

[a] The theoretical concentration of parathion in the pit for all the formulations was adjusted to 1 p.p.m.

[b] The magnitude of release at this interval for all concentrations except the 10 percent prepared with Chevron Light Solvent was about 100 percent. For the AR–60 formulations the highest release of parathion was 54 percent for the 10 percent parathion formulation. The rest of the formulations prepared with this solvent were very poor.

[c] All the formulations prepared with this solvent were tested at 0.0125 p.p.m. theoretical concentration in the cups.

[d] Formulations prepared with this solvent were tested at 0.02 p.p.m. in the cups.

here. However, the lag in release of 1- and 0.5-percent formulations on the 30/60 mesh granules was very little compared to the lag between the releases of these two formulations utilizing coarser mesh granules (see Table 4).

To investigate this relationship, three grades of AA-LVM attapulgite granules were employed. These were in the standard mesh sizes of 30/60, 20/40, and 16/30, the last having the coarsest particles.

These granules were impregnated with

TABLE 4.—The effect of toxicant concentration in the formulation and of granule size on the efficiency of parathion granules [a]

| Granule size | Percent parathion conc. | Avg. percent mortality of larvae at intervals (hours) | | | |
|---|---|---|---|---|---|
| | | 8 | 24 | 48 [b] | 72 |
| 30/60 | 1.0 | 45 | 100 | 96 | 100 |
| | 0.5 | 65 | 100 | 97 | 100 |
| 20/40 | 1.0 | 17 | 64 | 85 | 98 |
| | 0.5 | 68 | 92 | 100 | 98 |
| 16/30 | 1.0 | 8 | 21 | 49 | 98 |
| | 0.5 | 25 | 32 | 92 | 96 |

[a] The parathion concentration was adjusted to 1 p.p.m. in the jar and further diluted and tested at 0.01 p.p.m. in the cups against the larvae. The carrier was AA-LVM attapulgite granules and the solvent used in impregnation was Chevron Light Solvent.

[b] Percent release of parathion at this interval for the 0.5 percent formulations ranged from 86 to 100 percent. The finer-mesh granules released 100 percent while the coarsest mesh released 86 percent of the toxicant.

GRANULE SIZE. Particle size plays an important role in the use of granular insecticides. Large particles have physical advantages and are cheaper and easy to distribute with either ground equipment or aircraft. Large granules have a small amount of fines and most of the particles carrying the toxicant are liable to penetrate through a plant canopy, leaving very little toxic residues on the plants. Finer-mesh granules (e.g., 30/60 mesh) contain anywhere from 2 to 10 percent fine particles which would lodge on plant surfaces or drift away from the locale where treatment is carried out.

Coarse materials, on the other hand, have fewer particles per unit weight than finer-mesh materials. Treatment with coarser-mesh materials at rates equal to finer-mesh materials would undoubtedly result in poor distribution, incomplete coverage of the treated area, and fewer particles of the material per unit area. Above all these considerations, the relationship between particle size and release of the toxicant must also be elucidated.

parathion at 1- and 0.5-percent concentrations using Chevron Light Solvent. The results of this study indicated that particle size markedly influenced the speed of release of parathion. For both the 1- and 0.5-percent formulations the percent release of the toxicant generally decreased as the particle size increased (Table 4). Within the range of experimental variation, the extent of release of the 0.5-percent formulations on 30/60 mesh and 20/40 mesh granules at all intervals was essentially the same. The 0.5-percent formulation both on the 20/40 mesh and 16/30 mesh granules released parathion faster at the 8-, 24- and 48-hour intervals than the 1-percent formulations on these carriers. The difference between the two concentrations on the 30/60 mesh granules was slight and was obvious only at the 8-hour interval.

Selection of a specific size granule for mosquito control would depend on the speed desired for release of the toxicant and on the type of breeding grounds to be treated. For quick control in breeding grounds without food and forage crop

stands or without dense emergent plant canopy, the finer-mesh materials (30/60) can be employed advantageously. Where treatment of forage and food crop stands is contemplated for mosquito control, the coarser materials (20/40 and 16/30 mesh) should be considered. For reasons explained above, the use of materials coarser than the 16/30 grade should be discouraged where quick mosquito larval reduction is desired.

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# FIELD-STUDY COMPARISONS BETWEEN INSECTICIDAL GRANULES AND EMULSION CONCENTRATES AGAINST MOSQUITO LARVAE

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The successful use of granular formulations of insecticides in thick stands of rice plants was reported by Whitehead (1951). Bentonite pellets coated with any one of several insecticides were very effective against larvae of *Psorophora confinnis* (L.Arr.) and *P. discolor* Coquillett where conventional spray applications were of no value. Rees (1953) found that bentonite and diatomaceous earth granules containing heptachlor or dieldrin were superior to sprays in several respects, including rate of treatment and ease of handling. The results of Rees *et al.* (1953) demonstrate the superior control of *Aedes* and *Culex* larvae by granular formulations of insecticides in fields having dense and extremely matted vegetation. These authors also noticed the unusual residual effect of parathion, applied at the rate of 0.2 lb. actual toxicant per acre on diatomaceous earth granules, which retained effectiveness for more than 2 to 3 weeks after application. Keller *et al.* (1954) published the results of field tests of various granulated insecticides against larvae of *Aedes taeniorhynchus* (Wied.) and *Ae. sollicitans* (Wlkr.) in salt marshes with heavy vegetation. In these tests granules of bentonite were generally slightly more effective than those of attapulgite except at lower dosages. The results also indicated that aerial applications of granulated insecticides in salt marshes with heavy vegetation were more effective than spraying. The effects of size and composition of granules on larvicidal

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action were investigated by LaBrecque *et al.* (1956). Various types of clay granules were impregnated with several different kinds of insecticides and tested against the larvae of *Anopheles quadrimaculatus* Say, *A. crucians* Wied., and *Aedes aegypti* (L.). Pyrophyllite and diatomaceous earth granules were found to be slightly superior to attapulgite or bentonite as carriers. Granules of mesh sizes ranging from 5–10 to 100 were found to be equally effective carriers. Granules prepared with highly volatile solvents such as xylene and carbon tetrachloride were as effective as those prepared with solvents of low volatility such as fuel oil. Differences in the insecticides, their concentrations and the types of granules used in the formulation affected the rate and amount of insecticide released in water (Weidhaas, 1957). Lewallen and Brydon (1958) achieved satisfactory control of *Culex tarsalis* Coquillett and *Anopheles freeborni* Aitken larvae with Dylox and Guthion formulations on montmorillonite granules. Successful control of *Aedes, Anopheles,* and *Psorophora* larvae by the use of a new granular paris green formulation was demonstrated by Rogers *et al.* (1958). Mulla and Axelrod (1959) reported the results of studies of factors which influenced the rate of release of toxicants from granules in laboratory tests. In general, the investigations reported above utilized granular formulations alone and emulsion concentrates were not tested concurrently. The efficacy of granules can be more meaningfully assessed by carrying out parallel tests with spray formulations.

METHODS AND MATERIALS. All the tests reported herein were conducted on irrigated pastures situated in Fresno and Kings Counties, California, with 3rd and 4th instar larvae of *Aedes nigromaculis* (Ludlow) and *Culex tarsalis* Coquillett. Experimental plots of 1/32 acre were marked with red flags. The lengths and widths used were varied according to the size of the pasture check rows. An effort was made to select a uniform segment of pastureland with respect to larval density and vegetative growth. Despite this, variations in depth of water and height of vegetation could not be kept constant from one test to another. The pretreatment larval index was made by taking 20 dips at random in each experimental plot and this index was compared with post-treatment dips made 24 hours later. The ratio of the post- and pretreatment indices reveals the percentage control. All tests were run during the months of July, August, and September, 1959. Each test was replicated 3–5 times on different batches of larvae.

*Application of Insecticides.* Since the dosages required to give appreciable levels of larval mortality were very low, it was practically impossible to get a homogeneous distribution of the formulated granules over the experimental plots. To overcome this difficulty, appropriate types of untreated granules were used to dilute the weighed amount of the insecticidal granules. In order to attain a uniform pattern of distribution over the experimental plots the total weight of all the granular insecticides was kept constant at 100 gm./plot (about 7 lbs/acre). The insecticide granules and the untreated diluent granules were weighed out in ½ pint paper ice cream cartons and mixed thoroughly for at least 3 minutes.

The granules were broadcast by hand over the experimental plots. After a little experience a uniform pattern of distribution was attained.

*Insecticidal Compounds.* Descriptions of the insecticidal materials employed in these investigations are presented in Table 1.

The corresponding amounts of the spray formulations were measured out in 6 oz. glass bottles. Each spray sample was mixed in a 1-gallon spray tank with one-half gallon of tap water. The spray tank wand was equipped with a Teejet nozzle No. 8002. Spray applications were made at approximately 25–30 lb/sq. in. pressure.

*Testing of the homogeneity of the granular formulation dilution.* Since very small amounts of the formulated granules were required at each dosage, it was believed necessary that the homogeneity of the

TABLE 1.—Types and sources of formulation used in tests

| Insecticides | Type of formulation | Source |
|---|---|---|
| A. *Granular Materials* | | |
| Di-syston | 2.5%, on Attapulgite-LVM-A Size—20/40 mesh | Univ. of California Riverside [a] |
| Malathion | 10.0%, on Attaclay-AAlum Size—24/48 mesh | Sunland Industries Fresno, California |
| Parathion | 5.0%, on Attaclay-AAlum Size—24/48 mesh | " " |
| Thimet | 5.0%, on Attaclay-AAlum Size—24/48 mesh | " " |
| Trithion | 5.0%, on Attapulgite-RVM-A Size—30/60 mesh | Univ. of California Riverside [a] |
| B. *Spray Materials* | | |
| Di-syston | 2 lbs./gal. Emulsion Concentrate | Chemagro Chemical Co. New York 16, N. Y. |
| Malathion | 57% Emulsion Concentrate | American Cyanamid Co. New York 20, N. Y. |
| Parathion | 25% " " | " " |
| Thimet | 47.5% " " | " " |
| Trithion | 37% " " | Stauffer Chemical Co. New York 17, N. Y. |

[a] Dr. M. S. Mulla.

diluted granules be tested. Malathion, parathion and Thimet granules were employed in these tests. Three to four replications were run by the standard method described above.

RESULTS AND DISCUSSION. The larval mortality figures of diluted granular formulations for each dosage in different replications are presented in Table 2. For all three insecticides, malathion, parathion and Thimet, there seems to be a consistent level of larval mortality obtained for each dosage and in all replicates. Based on the results of these experiments, all the granular insecticides used in parallel tests with spray applications were prepared by weighing out individual samples and diluting them with the untreated granules.

In Table 3 the comparative effectiveness of granular and spray applications of Di-syston, malathion, parathion, Thimet and Trithion against the larvae of *Aedes nigromaculis* are shown. Only a limited number of tests with parathion granules was conducted on *Culex tarsalis* because of the difficulty in finding appropriate testing sites for this species in 1959 (Table 4). As can be seen from the tables, there were no outstanding differences in the effectiveness of spray and granule formulations.

Although the performances of the two types of applications were similar, the granular materials were superior in ease of handling and rapidity of application. They may also prove to be much safer than liquid formulations. In case of accident the risk of poisoning is much less with granular than with spray formulations. The granular formulations also have a potential use in pre-irrigation treatments and may possibly have a longer toxic residual action to larvae. Further field experiments are required to establish these points.

SUMMARY. Bentonite and attapulgite granules coated with Di-syston, malathion, parathion, Thimet and Trithion were compared with sprays at similar dosages

TABLE 2.—Extent of variations in *Aedes nigromaculis* (Ludlow) larval mortality for malathion, parathion, and Thimet granules at varying dosage levels prepared by dilution with untreated granules

| Insecticides and dosages (lb/acre of toxicant) | 24-Hour percent mortality | | | | Average Percent mortality |
|---|---|---|---|---|---|
| | Replicates | | | | |
| | 1 | 2 | 3 | 4 | |
| *Malathion* | | | | | |
| 0.500 | 100 | 100 | 97 | – | 99 |
| 0.250 | 95 | 99 | 100 | – | 98 |
| 0.125 | 86 | 99 | 78 | – | 88 |
| *Parathion* | | | | | |
| 0.100 | 100 | 100 | 100 | 100 | 100 |
| 0.050 | 100 | 100 | 100 | 100 | 100 |
| 0.025 | 99 | 98 | 100 | 100 | 99 |
| 0.0125 | 90 | 83 | 100 | 99 | 93 |
| *Thimet* | | | | | |
| 0.100 | 100 | 100 | 100 | 100 | 100 |
| 0.050 | 100 | 100 | 100 | 100 | 100 |
| 0.025 | 93 | 97 | 99 | 84 | 93 |
| 0.0125 | 95 | 100 | 93 | 41 | 82 |

TABLE 3.—Comparative percent larval mortality observed for a few organophosphorus insecticides in granular and spray field applications to *Aedes nigromaculis* (Ludlow) larvae

| Compounds and dosages (lb/acre of toxicant) | Percent mortality [a] | | | |
|---|---|---|---|---|
| | Spray application | | Granular application | |
| | Average | Range | Average | Range |
| *Di-Syston* | | | | |
| 0.50 | 94 | 87–100 | 74 | 53–94 |
| 0.25 | 43 | 23–63 | 82 | 82–82 |
| 0.10 | 54 | 25–76 | 43 | 42–43 |
| *Malathion* | | | | |
| 0.500 | 98 | 96–100 | 99 | 96–100 |
| 0.250 | 96 | 88–100 | 99 | 98–100 |
| 0.125 | 93 | 83–98 | 92 | 78–100 |
| 0.0625 | 75 | 53–98 | 80 | 74–87 |
| *Parathion* | | | | |
| 0.050 | 99 | 99–100 | 100 | 99–100 |
| 0.025 | 93 | 80–100 | 99 | 98–100 |
| 0.0125 | 92 | 77–100 | 94 | 83–100 |
| 0.00625 | 68 | 45–91 | 82 | 73–92 |
| *Thimet* | | | | |
| 0.050 | 98 | 92–100 | 91 | 64–100 |
| 0.025 | 91 | 79–100 | 93 | 84–99 |
| 0.0125 | 76 | 38–99 | 78 | 41–100 |
| 0.0625 | 53 | 13–93 | 33 | 25–41 |
| *Trithion* | | | | |
| 0.20 | 93 | 87–100 | 89 | 74–87 |
| 0.10 | 85 | 59–100 | 75 | 57–92 |
| 0.05 | 57 | 30–92 | 90 | 83–95 |

[a] Each dosage was replicated 3 to 5 times on different batches of larvae.

TABLE 4.—Larval mortality of *Culex tarsalis* with parathion in granular and spray applications in a single experiment

| Dosage lb/acre | Percent mortality [a] Spray application | Granular application | |
|---|---|---|---|
| 0.100 | 100 | 100 | — |
| 0.050 | 100 | 100 | 95 |
| 0.025 | 100 | 78 | — |
| 0.0125 | 78 | 52 | — |

[a] Twenty-four-hour post treatment counts.

for the control of late instar larvae of *Aedes nigromaculis* and *Culex tarsalis*. The granular formulations were about as effective as the sprays.

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# EFFECT OF VARYING DEPTHS OF WATER WITH IDENTICAL SURFACE AREA ON MOSQUITO LARVAL MORTALITY USING COMMERCIAL MALATHION AND PARATHION EMULSION CONCENTRATES

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There are many factors which may affect the results of tests of mosquito larvicides. Some of these which have been studied are age, nutritional state and density of larvae, surface area-volume relationships, type of container and amount and type of solvents (Kruse *et al.*, 1952, and Weidhaas and Gahan, 1958). Strong evidence of joint action of solvent and toxicant was demonstrated by Hawkins (1956). Hawkins and Kearns (1956) published results of ionic environment and zeta potential in relation to suspension stability of DDT. Differences in the susceptibility of larvae of various species of mosquitoes to a particular insecticide, and of the same species to different insecticides, were observed by Schmidt and Weidhaas (1958). These authors (1959) also studied the effect of variations of technique on the mortality of mosquito larvae in laboratory tests. In spite of all these observed differences in mortality due to testing method, it is customary to recommend larvicide application rates on an area basis without regard to the depth of water.

Most larviciding formulations available are emulsion concentrates which are diluted with water, and when applied to water disperse rather uniformly through it. It is therefore to be expected that sprays applied to deep water will be less effective than when shallow water is treated. The objective of this study was to test the effect of water depth on larval mortality when emulsion concentrate solutions of insecticides are applied to the water surface.

MATERIALS AND METHODS. Wide-mouth, glass, gallon jars, 14.6 cm. in diameter, were employed as test containers. The surface area of water inside each jar was 190 $cm.^2$ Tap water of pH 7.4 was used in all tests.

Malathion and parathion emulsion concentrates, 57 and 25 percent by weight respectively, were selected for these studies. Both insecticides were formulated by American Cyanamid Company, New York, N. Y.

Fourth instar larvae of the Bakersfield strain of *Culex pipiens quinquefasciatus* Say were utilized in the tests. This strain of mosquitoes was colonized in 1952 by the Kern County Mosquito Abatement District from adults collected in Bakersfield. A sub-colony was started at the Bureau of Vector Control Field Station at Fresno in 1955.

Thirteen one-gallon jars of identical size were used for the tests. Four hundred thirty ml. of water placed in a jar provided a medium of 2.5 cm. deep. Each successive 475 ml. of water increased the depth by an increment of 2.5 cm. Two sets of 6 jars each were prepared for the two dosage rates of each insecticide. Within each set, an appropriate volume of water was added to give depths of 2.5, 5.0, 7.5, 10.0, 12.5, and 15.0 cm. One jar containing water 7.5 cm. deep was employed as an untreated control for the two sets. Each insecticide was tested at two dosage levels. These two dosages were selected to kill approximately 50 and 90 percent of the larvae when applied to water 2.5 cm. deep. These dosages were 0.3241 and 0.4140 mg. malathion/$cm.^2$ of water surface and 0.0065 and 0.0084 mg. of parathion.

One hundred larvae were introduced into each jar before the addition of the insecticide. Appropriate amounts of malathion and parathion formulations were weighed on an analytical balance and serial dilutions were made in distilled water. One ml. of the final dilution was added to each jar by pipette, dropwise, care being taken to treat only the water surface. The jars were left undisturbed for the entire exposure period to avoid mechanical mixing of the test medium. After 24 hours each larva was probed with a needle and those which failed to respond were tabulated as dead. All tests were performed at $25 \pm 3°$ C. Each test was replicated three times.

In another experiment, 3 series of jars with 3 jars in each series were employed to determine the distribution pattern of the emulsion concentrate of malathion in varying depths of water. To the first, second, and third series of jars were added, respectively, 430, 860 and 1720 ml. of water to produce depths of 2.5, 5.0, and 10.0 cm. Malathion was applied to each of the three series at the rate of 0.4140, 0.8280, and 1.6560 mg./$cm.^2$ of water surface. Although these three dosages differ in terms of weight applied per unit of surface area, the final concentration of malathion in the water of each series would be approximately the same if it were homogeneously distributed.

RESULTS. The effect of depth (or volume) of water on mortality of larvae is shown in Table 1. Each figure in the table is an average of three replicates. It can be seen that the effectiveness of the insecticides was greatly reduced by increasing the depth of the medium. Larval mortality was negligible in tests where the water was 10 cm. or more in depth. Increasing the depth of the water affected the performance of the two insecticides similarly.

These results indicate that when equal amounts of insecticide are applied to equal surface areas, the mortality rate is inversely

TABLE 1.—Twenty-four hour mortality of *Culex pipiens quinquefasciatus* larvae exposed to malathion and parathion emulsions applied at different dosage rates (mg./cm.$^2$) to varying depths of water

| Depth of water (cm.) | Malathion | | Parathion | |
|---|---|---|---|---|
| | 0.3214 mg./cm.$^2$ | 0.4140 mg./cm.$^2$ | 0.0065 mg./cm.$^2$ | 0.0084 mg./cm.$^2$ |
| 2.5 | 53.7 | 88.0 | 35.3 | 91.0 |
| 5.0 | 18.7 | 31.0 | 5.3 | 37.7 |
| 7.5 | 6.7 | 15.7 | 2.0 | 6.0 |
| 10.0 | 0.7 | 4.3 | 1.0 | 3.7 |
| 12.5 | 0.0 | 2.3 | 2.0 | 1.3 |
| 15.0 | 0.0 | 0.0 | 1.3 | 1.3 |

related to the depth of water. If the mortality rate is plotted against the square of the depth of water, an approximately straight line results, suggesting that the mortality rate is inversely related to the volume of medium. If the mortality rate is plotted against the dosage in terms of weight of insecticide per volume of water an approximately straight line results which suggests a uniform dispersion of insecticide throughout the aqueous medium. This is especially true of malathion. With parathion the kill of larvae at high dilutions is greater than expected which suggests a less homogeneous distribution of the insecticide with larger amounts occurring in the zone where larvae are concentrated.

When similar tests were done in which the weight of insecticide per unit of surface area was increased as the depth increased, the mortality rate did not vary with increasing depth of water (Table 2).

DISCUSSION. The data presented in Table 1 indicate that a given dosage of insecticide applied to different volumes of water is homogeneously distributed throughout the water so that the concentration of the insecticide is decreased as the volume of water is increased. These results are confirmed by the data shown in Table 2 which indicate that when the weight of insecticide per volume of medium is held constant, the mortality rate does not change with depth of medium. It is expected that emulsion concentrates of many other insecticides will be found to behave in a similar fashion. It remains to be shown whether these laboratory findings will prove true under field conditions. The present studies strongly suggest, however, that the usual method of calculating dosages, i.e., weight per unit of surface area, has some limitations. If all mosquito breeding places are treated with the same dosage rate of larvicide (based on area), many larvae, especially those in deeper standing water, will undoubtedly survive. From this the impression may be created that the population has become resistant to the insecticide. The depth of water over the area to be treated should therefore be considered when selecting an effective dosage, especially if the formulation used can be expected to attain a state of homogeneous distribution in the water.

TABLE 2.—Twenty-four hour mortality of *Culex pipiens quinquefasciatus* larvae exposed to malathion emulsion applied at similar dosage rates (mg./cm.$^2$) with respect to volume of water [1]

| Depth of water (cm.) | Dosage (mg./cm.$^2$) | Mortality (percent) | | | Average |
|---|---|---|---|---|---|
| 2.5 | 0.4140 | 95 | 90 | 96 | 93.7 |
| 5.0 | 0.8280 | 95 | 93 | 94 | 94.0 |
| 10.0 | 1.6560 | 96 | 93 | 91 | 93.3 |

[1] Actually, the dosages were 0.183, 0.174, and 0.170 mg./cm.$^2$, respectively, the variation being due to the non-uniform nature of the bottoms of the jars.

SUMMARY. The effects of similar rates of application (mg./cm.$^2$ of water surface) of malathion and parathion emulsion concentrates to varying depths of water with identical surface area were investigated by employing *C. p. quinquefasciatus* larvae. A given dosage (based on mg./cm.$^2$) was less effective as the depth of water was increased. The lower mortality with increasing depth of water was attributed to homogeneous distribution of the insecticide throughout the water.

When malathion was applied at a constant rate of weight of insecticide to volume of water, varying depths did not affect the larval mortality.

This information suggests that the common practice of applying mosquito larvicides on the basis of surface area of water without consideration of water depth may result in ineffective larval control in deep water.

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## ENTOMOLOGISTS WANTED

The Pan American Sanitary Bureau, World Health Organization, is recruiting entomologists for work in malaria eradication projects in different countries of Latin America. Must have Ph.D., or Sc.D. in entomology or related discipline. Knowledge of Spanish advantageous. Work involves quantitative field studies of anophelines, their life history, habits and ecology. Starting salary $6,000 per annum plus liberal allowances, income tax reimbursable. Generous fringe benefits. For further information, write to Personnel Officer, PASB/WHO, 1501 New Hampshire Ave. N.W., Washington 6, D. C.

# A NEW THERMAL-AEROSOL GENERATOR FOR DISPERSING INSECTICIDAL FOGS FROM A STEARMAN AIRPLANE

JACK SALMELA,[1] A. J. SIDLOW,[1] AND A. NELSON DAVIS[2]

The use of an exhaust-generated thermal aerosol apparatus on an airplane is not new. It has been utilized by the U. S. Department of Agriculture (Lindquist *et al.,* 1945), the Tennessee Valley Authority (Metcalf *et al.,* 1945), and other agencies. However, this equipment was never widely accepted for the control of adult mosquitoes in Florida.

The first attempt to control mosquitoes with thermal aerosols by the Brevard Mosquito Control District was made in 1951 with two Dynafog machines and DDT as the insecticide. However, because of the poor results probably due to mosquito resistance to DDT created by extensive spraying of the breeding areas by airplanes, no additional thermal aerosol ground units were purchased. The District turned to ground spray units instead.

When the Entomological Research Center, Florida State Board of Health, Vero Beach, reported excellent results with malathion as a thermal aerosol in ground equipment (Rogers *et al.,* 1957), the District again became interested in the use of fog in the control of adult mosquitoes.

To make ground control practical in an area as large as Brevard County, which is 72 miles long and has a population of slightly over 100,000, it was estimated that more than 15 units would be needed. Therefore, owing to the cost of machines on the market, it was decided that the District would manufacture its own ground foggers.

A surplus airplane engine was mounted in a large tube, and fog was produced by injecting the insecticide directly into the exhaust pipes. This apparatus was so successful (Rathburn and Rogers, 1959) that it was decided to install thermal-aerosol equipment on one of the six District-owned Stearman (PT–17) spray planes. This plane was equipped with an exhaust venturi constructed in accordance with the recommendations of the U. S. Public Health Service and the Tennessee Valley Authority (Krusé and Metcalf 1946).

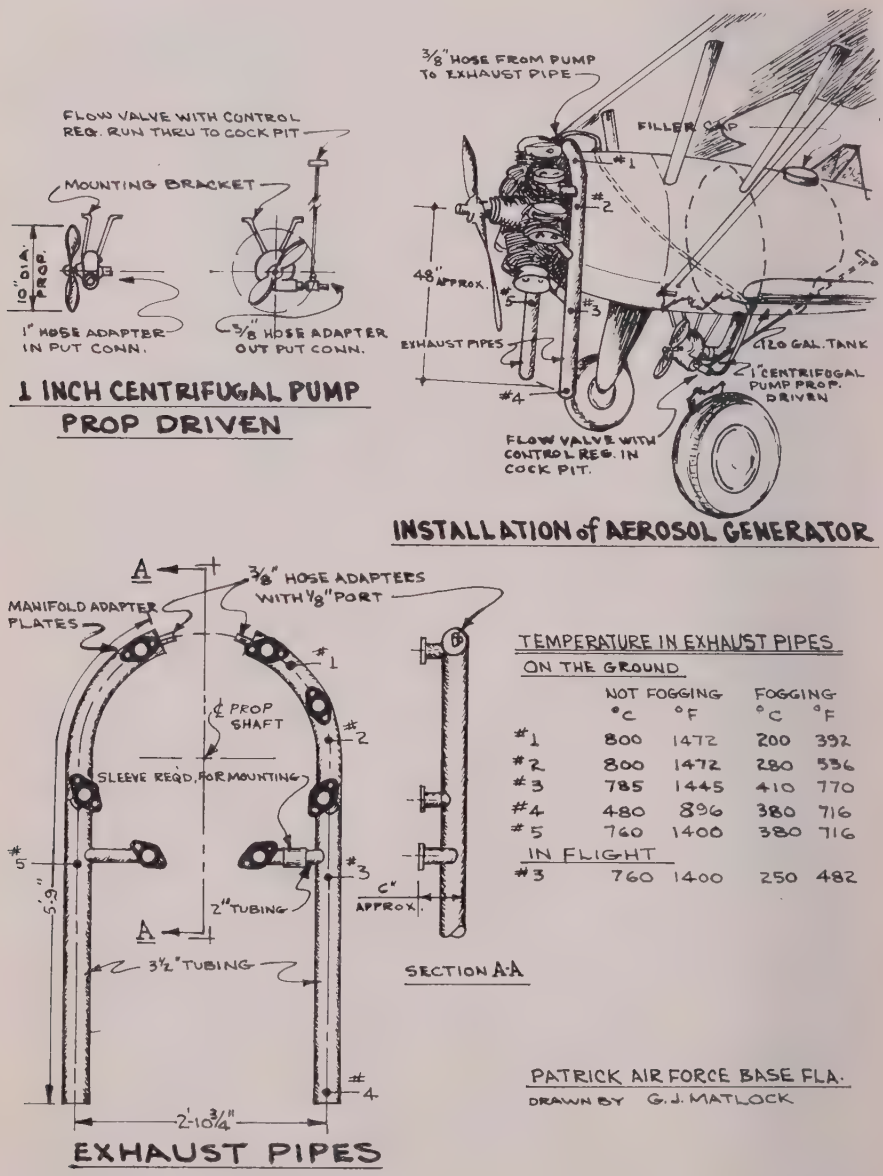
This unit was used for a short time during the spring of 1958 and showed promising results. However, the back pressure on the engine created by the restriction in the venturi was intolerable. Therefore, since the ground unit worked so well with no restriction, it was decided to discard this unit and make one with no restriction.

A detailed drawing of the exhaust generator unit is shown in Figure 1. The original exhaust collector ring was completely removed from the airplane and left and right exhaust pipes of common soft iron exhaust-pipe material 3½ inches in diameter, were made to fit the engine. The left pipe collects the exhaust from four cylinders and the right one from the other three. The pipes are curved to conform to the shape of the radial engine, extend straight down approximately 30 inches below the bottom of the engine, and discharge between the landing gear. The insecticide is introduced at the top of the two pipes by a 1-inch air-driven centrifugal pump; a ⅛-inch restriction in the line controls the output at approximately 150 gallons per hour (Figure 2).

The advantages of this apparatus are as follows:

1. A fog plane provides a 200-foot swath, compared with the 100-foot swath furnished by the spray plane. A very large area can be treated with each load; thus time is saved in going to and from the area to be treated. One takeoff and

[1] Brevard Mosquito Control District.
[2] Entomology Research Division, Agric. Res. Serv., U.S.D.A.




TEMPERATURE IN EXHAUST PIPES

ON THE GROUND

| | NOT FOGGING °C | NOT FOGGING °F | FOGGING °C | FOGGING °F |
|---|---|---|---|---|
| #1 | 800 | 1472 | 200 | 392 |
| #2 | 800 | 1472 | 280 | 536 |
| #3 | 785 | 1445 | 410 | 770 |
| #4 | 480 | 896 | 380 | 716 |
| #5 | 760 | 1400 | 380 | 716 |
| IN FLIGHT | | | | |
| #3 | 760 | 1400 | 250 | 482 |

PATRICK AIR FORCE BASE FLA.

DRAWN BY G. J. MATLOCK

FIG. 1.—Installation of exhaust aerosol generator on Stearman (PT—17), with details of the pump and exhaust pipes, and temperature data at selected sites in the pipes.

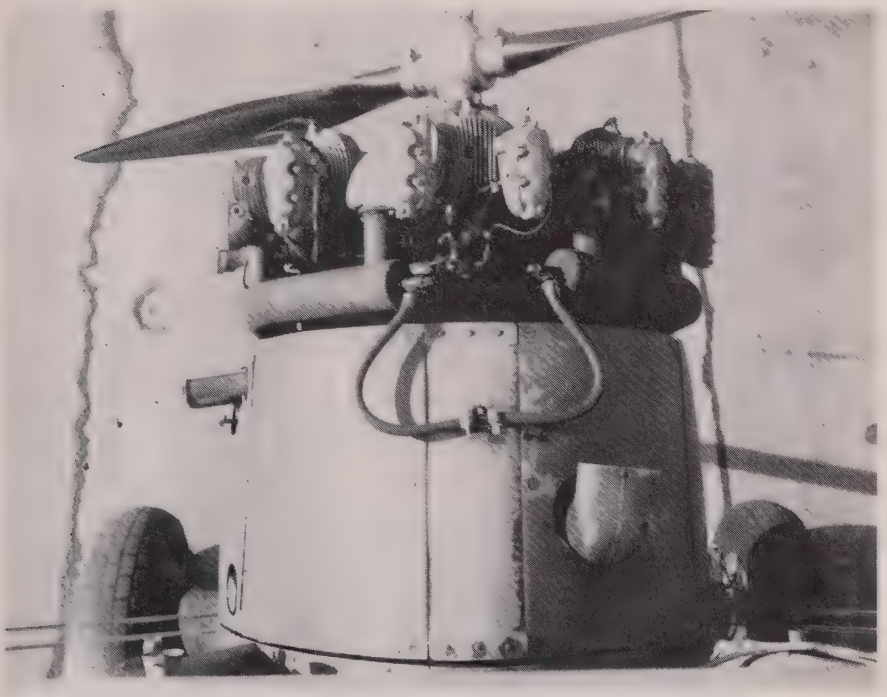


Fig. 2.—Point of introduction of insecticide solution into top of exhaust pipes.

landing are required, compared with at least six of each operation with a spray plane.

2. The small droplets [3] do not spot automobiles. They also do not kill minnows and other wildlife.

3. The fog penetrates dense foliage more adequately than the spray.

4. The pilot can see the fog spread by the first pass and use it as a guide for succeeding ones. Thus flagmen can be eliminated.

5. Since there is no noticeable drag, the fog apparatus can be installed on the airplane in combination with that used for spraying or dusting.

6. Fog is easy to work with at night. Thus a large area can be treated while the mosquitoes are active.

7. The cost per acre is almost one quarter of that required for spraying.

The components and cost of a formulation used with excellent results in 1958 and 1959, are given in Table 1. Experimentation is not yet complete but preliminary studies indicate that an aerosol containing 10 percent v/v of 90 percent malathion and a fog oil cheaper than that used in 1959 can be recommended. This formulation, which reduces the cost from $0.15 to $0.114 per acre, will be used in 1960. The ingredients are also given in Table 1.

The average flight time, number of acres treated, and the cost of application of the malathion thermal aerosols and spray for each 120-gallon load are given in Table 2.

[3] On March 4, 1960, A. H. Yeomans, Agric. Res. Div., U.S.D.A., Beltsville, Md., collected droplets and found they had an average mass median diameter of less than 5 microns.

TABLE 1.—Cost of materials used in malathion aerosols and sprays per 100 gallons

| | Aerosol | | | | Spray | |
|---|---|---|---|---|---|---|
| | Percent (v/v) | | Cost | | Percent (v/v) | Cost |
| Material | 1959 | 1960 | 1959 | 1960 | | 1959 |
| Malathion (90%) | 15 | 10 | $123.60 | $79.00 | 2 | $16.48 |
| Fog oil | 15[a] | 10[b] | 6.15 | 2.40 | — | — |
| HAN[c] | 15 | 10 | 4.65 | 3.10 | — | — |
| Diesel fuel | 55 | 70 | 6.19 | 7.88 | 98 | 11.03 |
| Total cost | | | $140.59 | $92.38 | | $27.51 |

[a] Standard Oil No. 1.
[b] Standard Oil No. 345 (in 5,000-gallon lot).
[c] Heavy aromatic naphtha, auxiliary solvent.

TABLE 2.—Costs of operations

| | 1959 | | 1960 |
|---|---|---|---|
| | Aerosol | Spray | Aerosol |
| Flight time, minutes | 99 | 27 | 99 |
| Acres treated | 1551 | 120 | 1551 |
| Cost of material | $ 168.70 | $ 33.01 | $ 110.86 |
| Cost of plane and pilot | $ 66.00 | $ 18.00 | $ 66.00 |
| Total cost | $ 234.70 | $ 51.01 | $ 176.86 |
| Cost per acre | $ 0.15 | $ 0.425 | $ 0.114 |

The costs were computed for a 220-hp. Stearman airplane and pilot at $40 per hour, flying at 80 m.p.h., dispersing 16 gallons of spray per minute in 100-foot swaths, or 2.5 gallons per minute as a fog in 200-foot swaths, each carrying 120 gallons per load.

While making routine treatments of large areas with fog, the pilot seldom finds it necessary to make a special effort to fly crosswind, as must be done with a spray. Even during periods of calm air the 200-foot swaths completely cover the area. Ordinarily the pilot prefers to select the longest runs to begin with in order to lighten the load as soon as possible, which in turn makes the airplane easier to maneuver; he then works out the shorter runs. However, in areas where a choice of runs is available and when the wind velocity is less than 10 m.p.h., crosswind flying beginning on the upwind side is preferred. With this method the body of fog drifts along as the airplane progresses and each pass increases the concentration (Figure 3).

In winds above 10 m.p.h. it seems to be necessary to fly almost parallel with the direction of the wind. When the line of flight is not exactly with the direction of the wind, it is advisable to start on the upwind side and work across; thus the body of fog is increased each time. Excellent results have been obtained over large areas using this method in winds up to 25 m.p.h. (Davis *et al.*, 1960). Above this wind velocity it is not safe to fly a loaded airplane at treetop level.

Since 1950 the District has had a waiver for low flying at night for the purpose of spraying. Because of the inversion of the temperature gradient, night flying increases the effectiveness of spraying as well as fogging. By utilizing moonlight, very

Fig. 3.--Aerial fogging with a Stearman (PT-17) airplane.

little flying has to be done in total darkness. Except on the rare occasions when the fog stratifies due to air currents and does not descend to the ground, aerial fogging works exceptionally well at night. Often the fog gets so dense that the swath width can be increased to as much as 400 feet and excellent coverage is still obtained.

A thermocouple was installed on the airplane at Patrick Air Force Base.[4] The temperature was taken at five different locations inside the exhaust while the engine was being run at 1,800 r.p.m. on the ground, before and after the fog was turned on, and at one location before and after the fog was turned on while in flight. The results are given in figure 1.

In conclusion, it should be mentioned that inasmuch as this apparatus makes it possible to treat entire broods of newly emerged adults over large areas, it would be reasonable to believe that a resistance problem could be created. The District has, on several occasions of extra heavy emergence near populated areas, used this method to apparently annihilate broods of

[4] This installation was made possible through the courtesy of H. J. Crawford, Entomologist, Patrick Air Force Base.

mosquitoes. If discretion were not used, and an effort made to treat all broods of mosquitoes upon emergence, resistance would undoubtedly occur.

SUMMARY. A new thermal-aerosol generator has been developed for the aerial dispersal of insecticidal fogs. This unit consists of essentially left and right exhaust pipes constructed on common exhaust-pipe material 3½ inches in diameter. The insecticide solution is introduced at the top of the pipes by a 1-inch air-driven centrifugal pump at a rate of approximately 150 gallons per hour. The use of a thermal aerosol containing 15 percent of a commercial 90 percent-malathion solution, 15 percent of a heavy aromatic naphtha, 15 percent of a fog oil, and 55 percent of a No. 2 diesel fuel has resulted in excellent control of adult mosquitoes when the plane dispersed 200-foot swaths.

Preliminary droplet-size studies showed the fog to have a mass median diameter of less than 5 microns.

Temperatures inside the exhaust pipes were recorded at five locations. In flight the temperature at the hottest location was 1400° F.; during fogging it dropped to 482°.

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**DESPLAINES VALLEY MOSQUITO ABATEMENT DISTRICT**

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# FIELD TESTS WITH MALATHION FOGS DISPERSED FROM AN AIRPLANE FOR THE CONTROL OF ADULT SALT-MARSH MOSQUITOES

A. NELSON DAVIS,[1] JACK SALMELA,[2] AND C. B. SPENCER, JR.[2]

For a number of years airplanes have been used to disperse insecticidal sprays aimed at controlling mosquito adults. This method has proved to be faster but not so economical as ground-operated thermal aerosol generators. The chief restricting factor is the limited area that can be treated with a single airplane load. In an effort to overcome this limitation, the Brevard Mosquito Control District, Brevard County, Fla., developed a specially constructed exhaust generator for dispersing aerosols from a Stearman (PT–17) airplane. This equipment differs from that previously used for aerial adulticiding insomuch as the aerosol is produced as a "dry fog."

The utilization of the exhaust of an airplane to disperse insecticides for controlling mosquitoes is not new. In a publication prepared by the U. S. Department of Agriculture (1946) the history of the early developments in this field is reviewed. This method was first investigated at the Orlando, Fla., laboratory of the USDA in 1943 by injecting DDT solutions into an extension of the exhaust pipe of a Piper Cub plane. Lindquist *et al.* (1945), in reporting on this equipment, stated that an intense smoke was produced and promising results were obtained against *Aedes taeniorhynchus* (Wied.) adults. The Tennessee Valley Authority also tested this type of equipment on a Stearman plane and reported excellent results against *Anopheles quadrimaculatus* Say larvae. However, subsequent studies by several investigators showed that there was an incomplete conversion of the solution to smoke, and the portion discharged as spray was principally responsible for killing most of the mosquitoes. Metcalf *et al.* (1945) found that by fitting a venturi section to the end of the exhaust pipe a fine spray with only a small amount of screening smoke was produced. This equipment was reported to be highly effective in controlling *A. quadrimaculatus* larvae and adults and also adults of pest species of *Aedes* and *Psorophora*.

The Brevard Mosquito Control District developed a new thermal-aerosol apparatus in 1958 and has been using it in routine control operations since that time. This equipment, described in detail by Salmela *et al.* (1960), consisted of dual exhaust stacks extending 30 inches below the 220 hp. engine. The emission rate was calibrated at 150 gallons per hour. The aerosol used in routine control operations contained 15 percent of a commercial 90 percent malathion solution, 15 percent of heavy aromatic naphtha, 15 percent of Standard Oil No. 1 fog oil, and 55 percent of No. 2 diesel fuel. The naphtha was used as an auxiliary solvent to keep the malathion in solution and the fog oil was added to increase the volume of fog and aid it in falling. This equipment and formulation showed promise in the routine control of adult mosquitoes but the need for an evaluation of effective swath widths and dosage rates was apparent.

Field tests were conducted during 1959 with this new equipment against natural populations of salt-marsh mosquito adults and caged *A. taeniorhynchus* adults from a laboratory strain.

The initial series of tests was conducted to determine the effective swath width for the formulation used in routine control. These tests were conducted on an exten-

[1] Entomology Research Division, Agr. Res. Serv., U.S.D.A.
[2] Brevard Mosquito Control District.

sive impounded salt marsh in north Brevard County which is transected with a series of dikes. Three stations were established on a dike at 200-foot intervals in line with the wind movement. Two screen cages containing about 25 adult females per cage were attached to a stake at each station. The stakes, each 6 feet high with a 3-foot crossarm, were placed upright in the soil and the cages suspended from wires attached to the crossarms (Figure 1). Applications were made between 6:40 and 7:25 a.m., on two days, from an altitude of 25 feet while flying 80 m.p.h., crosswind and at right angles to the line of stakes. Swaths were flown 100 feet upwind from the first station to determine the effectiveness of a single swath. Tests were also run to determine the effect of multiple swaths at intervals of 100 to 300 feet. Within 10 minutes after treatment the mosquitoes were anesthetized with carbon dioxide and transferred to clean cages (Figure 2). Mortalities were recorded after 12 hours. The results are given in Table 1. These tests indicated that effective control of adults could be obtained with an aerosol containing 15 percent of malathion when four swaths were applied at intervals up to 200 feet, but not 300 feet, all upwind of the first station.

A series of four tests was conducted to determine the effectiveness of routine treatments with 200-foot swaths over residential areas with varying degrees of vegetative cover. Prior to treatment cages of *taeniorhynchus* adults were suspended from wires attached to trees and shrubs in semi-open or heavily vegetated locations. Applications were made between 6:30 p.m. and 9:30 p.m. at an altitude of about 50 feet whenever possible, and approximately

FIG. 1.—Test cages attached to stake.

FIG. 2.—Apparatus used to transfer adult mosquitoes from exposure cage on right to holding cages on left. Carbon dioxide from the metal container is used to anesthetize adults in the plastic well in the center.

TABLE 1.—Swath-width studies with an aerosol containing 15% of a 90% malathion concentrate against caged *Aedes taeniorhynchus*. (Stakes 200 feet apart, extending downwind from final swath. 2 replications.)

| Swath pattern | | | | | | |
|---|---|---|---|---|---|---|
| Total number | Intervals (feet) | Distance upwind from Stake 1 (feet) | Percent mortality after 12 hours— Stake 1 | Stake 2 | Stake 3 | Wind velocity (m.p.h.) |
| 1 | — | 100 | 34 | 20 | 28 | 1–2 |
| 4 | 100 | 400–100 | 97 | 94 | 98 | 3 |
| 4 | 200 | 800–200 | 86 | 90 | 90 | 3–7 |
| 4 | 300 | 1,200–300 | 60 | 75 | 73 | 5–8 |

20 feet above trees and other obstructions, in winds of 3- to 25-m.p.h. velocity. When the wind movement was less than 10 m.p.h. the line of flight of the plane was at right angles to the direction of the wind; whereas, in winds in excess of 10 m.p.h. the line of flight was parallel to the direction of the wind. The size of the areas treated varied from 1,200 to 2,000 acres. A 30- to 60-minute time interval was allowed between treatment and transfer of the adults to clean holding cages. This time lapse was necessary to allow the aerosol cloud to dissipate or drift out of the area in which the cages were exposed. Mortalities were recorded after 12 hours.

The results of these tests are given in Table 2. Average mortalities of 89 to 99 percent were obtained. The lower kill occurred in a semi-open trailer park. Wind velocities of 15 to 20 m.p.h. prevailed during this test. The absence of vegetation of sufficient density to prevent the rapid passage of the aerosol over the area was the apparent reason for the low kill.

TABLE 2.—Evaluation of routine applications of aerosols containing 15% of malathion (90% concentrate) heavy aromatic naphtha, and fog oil in No. 2 diesel fuel against caged *Aedes taeniorhynchus*

| Area | Number of cages | Percent mortality after 12 hours | Wind velocity (m.p.h.) |
|---|---|---|---|
| Residential-wooded | 27 | 98 | 5–12 |
| | 31 | 99 | 15–25 |
| | 16 | 99 | 3 |
| Trailer park-semi-open | 12 | 89 | 15–20 |

Having shown that formulations containing 15 percent of malathion were highly effective, the next series of tests was conducted at an abandoned airstrip with formulations containing various concentrations of malathion and equal quantities of an auxiliary solvent (heavy aromatic naphtha) in No. 2 diesel fuel. Fog oil (15 percent by volume) was added to each formulation. As in the initial series, three stations were established at 200-foot intervals in line with the wind movement and two screen cages containing about 25 adult females per cage were attached to a stake at each station. Applications were made between 6:30 and 10:30 p.m. from an altitude of 25 to 40 feet while flying 80 m.p.h. crosswind and at right angles to the line of stakes. In these tests swaths were flown 800, 600, 400, and 200 feet upwind from the first station. Within 10 minutes after treatment, the mosquitoes were anesthetized with carbon dioxide and transferred to clean cages. The mortalities were recorded after 12 hours. The results of these tests are given in Table 3. Complete mortalities were obtained consistently with malathion at concentrations as low as 10 percent. Malathion concentrations of 5.0 and 7.5 percent produced 79–100 percent kills.

A fourth series of tests was conducted to evaluate three concentrations of malathion against natural populations of salt-marsh mosquito adults (predominantly *taeniorhynchus*). These studies were made in the Allenhurst-Shiloh area of Brevard County. Test plots of 180 and 900 acres were established in citrus groves. Applications were made during the first 1½ hours of daylight on four mornings from an altitude of 50 to 75 feet in winds of 1 to 7 m.p.h. The plane flew crosswind at swath intervals of 200 feet. The mosquito populations were sampled before and after treatment by two observers at 10 stations in the smaller plots and at 50 stations in the 900-acre plot. Control was determined by comparing the number of mosquitoes

TABLE 3.—Dosage tests with aerosols containing various concentrations (v/v) of malathion (90% concentrate), heavy aromatic naphtha, No. 2 diesel fuel, and 15% of fog oil against caged *Aedes taeniorhynchus*. (Stakes 200 feet apart, extending downwind from final swath. 3 replications.)

| Percent of malathion and heavy aromatic naphtha | Percent mortality after 12 hours at indicated distance from final swath | | | |
|---|---|---|---|---|
| | 200 feet | 400 feet | 600 feet | Average |
| 15.0 | 100 | 100 | 100 | 100 |
| 12.5 | 100 | 100 | 100 | 100 |
| 10.0 | 100 | 100 | 100 | 100 |
| 7.5 | 94 | 99 | 99 | 97 |
| 5.0 | 98 | 100 | 79 | 92 |

that landed on the two observers the day before and 3, 6, and 24 hours after application. These results are shown in Table 4.

TABLE 4.—Effectiveness of malathion aerosols against natural populations of adult salt-marsh mosquitoes. 3 replications

| Formulations (percent v/v) [a] | | | Pretreatment count (average per man per minute) | Percent reduction [b] after— | | |
|---|---|---|---|---|---|---|
| Malathion (90% conc.) | Naphtha | Fog oil | | 3 hours | 6 hours | 24 hours |
| 15 | 15 | 15 | 46 | 94 | 92 | +54 |
| 10 | 10 | 15 | 40 | 98 | 98 | +117 |
| 5 | 5 | 15 | 37 | 82 | 91 | 61 |

[a] No. 2 diesel fuel solutions.
[b] Plus sign indicates percent increase.

All formulations gave greater than 90 percent reduction after 6 hours, whereas after 24 hours the control was unsatisfactory owing to rapid reinfestation of the treated areas.

A fifth series of tests was conducted to evaluate two thiocyanate insecticides, Thanite and Lethane 384. Many mosquito control organizations have used these thiocyanates in combination with other insecticides as aerosols produced by ground-operated thermal aerosol generators. The principal combinations have been Thanite (isobornyl thiocyanoacetate, and related compounds) or Lethane 384 (2-(2-butoxyethoxy)ethyl thiocyanate) formulated with DDT, and more recently Lethane 384-malathion formulations. Both Thanite and Lethane 384 were tested alone and in combination with malathion. Each formulation contained an auxiliary solvent (heavy aromatic naphtha) in quantities equal to the insecticides and 15 percent of fog oil in No. 2 diesel fuel.

As in previous tests, three stations were established at 200-foot intervals in line with the wind movement. Two screen cages containing about 25 females per cage were attached to a stake at each station. Applications were made between 5:00 and 6:30 p.m. in wind movements of 3 to 8

TABLE 5. Effectiveness of thiocyanate insecticides and malathion (90% concentrate) against caged *Aedes taeniorhynchus*. (Stakes 200 feet apart extending downwind from final swath. 3 replications.)

| Insecticide and percent concentration (v/v[a]) | | Percent mortality after 12 hours at indicated distance from final swath | | | |
|---|---|---|---|---|---|
| | | 200 feet | 400 feet | 600 feet | Average |
| Malathion | 2.5 | 56 | 60 | 52 | 56 |
| Plus Lethane 384 | 5.0 | 20 | 19 | 8 | 16 |
| Plus Thanite | 5.0 | 32 | 41 | 18 | 30 |
| Lethane 384 | 15.0 | 20 | 6 | 8 | 12 |
| | 10.0 | 9 | 7 | 7 | 8 |
| | 5.0 | 17 | 10 | 3 | 10 |
| Thanite | 15.0 | 8 | 9 | 13 | 10 |
| | 10.0 | 5 | 9 | 3 | 6 |
| | 5.0 | 13 | 22 | 16 | 17 |
| None | [b] | 0 | 0 | 0 | 0 |

[a] An equal quantity of heavy aromatic naphtha was also used, plus 15 percent of fog oil, in No. 2 diesel fuel.
[b] Naphtha 15 percent, fog oil 15 percent, No. 2 diesel fuel 70 percent.

m.p.h. from an altitude of 25 feet while flying 80 m.p.h. crosswind and at right angles to the line of stakes. Again all test swaths were flown 800, 600, 400, and 200 feet upwind from the first station. The mosquitoes were transferred to clean cages within 10 minutes after treatment. The results of these tests are given in Table 5. Lethane 384 and Thanite were ineffective at concentrations as high as 15 percent, and, at 5 percent, did not add to the effectiveness of 2.5 percent of malathion. In fact, in these tests mortality with 2.5 percent of malathion alone was actually higher than that with the combinations.

SUMMARY. Field tests were conducted to evaluate a new thermal-aerosol exhaust generator designed to disperse insecticidal fogs from a Stearman airplane. No. 2 diesel fuel formulations containing various concentrations of malathion, an equal amount of heavy aromatic naphtha, and 15 percent of Standard Oil No. 1 fog oil were tested against natural populations of salt-marsh mosquito adults and caged *Aedes taeniorhynchus* (Wied.) from a laboratory strain.

This equipment, calibrated to disperse 150 gallons of solution per hour, was found to have an effective swath of at least 200 feet. Routine control treatments over residential areas with a formulation containing 15 percent of a commercial 90 percent malathion solution were highly effective in killing caged adults. Complete mortality of caged adults was obtained under experimental conditions at 10 percent, and greater than 90 percent mortality at 5 percent. Formulations containing 5 percent, 10 percent, and 15 percent produced satisfactory kills of natural populations.

Lethane 384 and Thanite were ineffective at concentrations as high as 15 percent and at 5 percent did not add to the effectiveness of 2.5 percent of malathion when tested against caged adults.

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JOINT MEETING

AMCA—CMCA

DISNEYLAND HOTEL

Disneyland, California

*January 30–February 2, 1961*

*(Please turn to page 321)*

# THIRD AND SECOND SEASON EFFECTIVENESS OF MOSQUITO LARVICIDE RESIDUALS AND FURTHER TRIALS OF GRANULAR DIELDRIN, HEPTACHLOR, AND DDT AT MINIMAL DOSAGES *

V. I. MILES

Field trials were initiated in 1956 at Chinook, Montana to evaluate the effectiveness of single preflood and post-flood applications of selected residual larvicides for controlling irrigation mosquitoes. Dieldrin, heptachlor, and DDT applied to plots early in the summer of 1956 as water emulsions and granular formulations at rates of 1.0, 1.5 and 3.0 pounds of toxicant per acre, respectively, gave essentially complete control of irrigation mosquitoes throughout the season (1). Second-season observations showed effective control throughout the 1957 season on 5 of 6 dieldrin plots, 1 of 3 heptachlor plots, and 1 of 2 DDT plots; and granular dieldrin applied in the spring of 1957 at 0.5 pound toxicant per acre provided complete control throughout the first (1957) season (2). Limited floodings of several of the experimental plots during both seasons and termination of mosquito production in the fall of 1957 precluded determination of the complete duration of larvicidal effectiveness. The present paper concerns observations continued in the 1958 season and further trials of granular dieldrin, heptachlor, and DDT at minimal dosages as preflood and post-flood residual larvicides.

The methods used in larvicide treatments and mosquito evaluations in 1956 and 1957 are given in the two references cited. Observations were made in 1958 on one treated plot that was not flooded during the two previous seasons, 3 plots that previously produced no more than 0.1 mature larvae per dip, and 14 plots on which no mosquito production occurred following treatment. As during previous seasons, both treated and untreated check plots were sampled for mosquito larvae twice each week when flooded. Sampling of treated plots was discontinued when the number of mature larvae and pupae present exceeded that of untreated check plots, indicating that the insecticidal treatments were no longer effective.

The third-season results from plots treated in 1956 are given in Table 1. No mature larvae were found on the single DDT plot during the 1958 season; however, this result is not conclusive in view of the fact very few larvae were found on the untreated check plot for this habitat type. Mature larvae were found on both heptachlor plots during their first floodings in 1958, indicating loss of residual effectiveness. Two of the five dieldrin plots under third-season observations produced mature larvae and pupae in July in numbers exceeding those from associated check plots. One of these two plots, however, showed some residual effectiveness on its first flooding in June. The remaining three dieldrin plots demonstrated considerable third-season effectiveness; some persistence of insecticide residual was evident on two plots during single floodings in May and on one plot flooded 4 times in June and July. Although both heptachlor and dieldrin treatments showed some residual effectiveness during the early part of the 1958 season, neither insecticide provided complete control of irrigation mosquitoes throughout the third season.

All of the 10 plots treated at Chinook in 1957 with granular dieldrin at the rate of 0.5 lb. toxicant per acre produced mature larvae during their first or second floodings in 1958 (Table 1). Although the numbers of larvae produced on the treated plots

* From the Technology Branch, Communicable Disease Center, Bureau of State Services, Public Health Service, U. S. Department of Health, Education and Welfare, Greeley, Colorado.

TABLE 1.—Third-year results of DDT, dieldrin, and heptachlor, and second-year results of granular dieldrin as residual larvicides Chinook, Montana, 1956–1958

| Insecticide | Formulation | Pre- or post flood | Location of plot | Date treated 1956 | Date treated 1957 | Lbs. toxicant per acre | Number of floodings 1956 | Number of floodings 1957 | Number of floodings 1958 | Average number mature larvae and pupae per dip from treated plots and untreated check plots in 1958 May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DDT | 1.5% Emulsion | Post | Roadside Ditch | 5/4 | — | 2.8 | 2 | 2 | 1 | 0.0/0.1 | 0.0/0.0 | 0.0/0.0 | 0.0/0.0 | 0.0/0.0 |
| Dieldrin | 10% Granular | Pre | Alfalfa Field | 6/4 | — | 1.0 | 2 | 4 | 2 | Dry | 1.1/19.5 | 7.9/5.4 | — | — |
| | | Post | Pasture | 6/6 | — | 1.0 | 1 | 2 | 1 | 0.4/2.9 | Dry | Dry | Dry | Dry |
| | 0.5% Emulsion | Pre | Roadside Ditch | 5/8 | — | 0.9 | 4 | 5 | 1 | Dry | Dry | 1.3/0.0 | Dry | Dry |
| | | Pre | Wasteland | 5/8 | — | 1.1 | 4 | 4 | 1 | 0.0/5.2 | Dry | Dry | Dry | Dry |
| | | Post | Wasteland | 6/1 | — | 1.0 | 3 | 5 | 4 | Dry | 0.0/2.8 | 0.3/3.3 | Dry | Dry |
| Heptachlor | 5% Granular | Pre | Pasture | 6/6 | — | 1.5 | 0 | 0 | 1 | Dry | 3.1/2.9 | — | — | — |
| | 0.75% Emulsion | Post | Roadside Ditch | 5/17 | — | 1.4 | 3 | 1 | 1 | 0.5/0.1 | 2.2/0.0 | — | — | — |
| Dieldrin | 2.5% Granular | Pre | Bluejoint Mead. | — | 5/10 | 0.5 | – | 2 | 1 | 0.3/4.1 | 0.0/0.7 | Dry | Dry | Dry |
| | | Pre | Bluejoint Mead. | — | 5/14 | 0.5 | – | 1 | 2 | Dry | 0.3/15.0 | 0.1/1.5 | Dry | Dry |
| | | Pre | Pasture | — | 5/13 | 0.6 | – | 1 | 2 | Dry | 2.3/5.5 | 1.4/1.1 | — | — |
| | | Pre | Pasture | — | 5/13 | 0.5 | – | 2 | 1 | 0.1/0.4 | Dry | Dry | Dry | Dry |
| | | Pre | Wasteland | — | 5/14 | 0.5 | – | 1 | 1 | Dry | Dry | 0.2/3.3 | Dry | Dry |
| | | Post | Bluejoint Mead. | — | 5/23 | 0.5 | – | 2 | 1 | — | 0.1/3.0 | Dry | Dry | Dry |
| | | Post | Pasture | — | 5/18 | 0.5 | – | 3 | 2 | 1.4/26.0 | 4.0/10.0 | — | — | — |
| | | Post | Roadside Ditch | — | 5/18 | 0.5 | – | 3 | 3 | 1.4/26.0 | 1.1/10.5 | 3.1/10.5 | Dry | Dry |
| | | Post | Roadside Ditch | — | 5/24 | 0.5 | – | 1 | 1 | 0.2/0.2 | 0.0/0.0 | 0.0/0.0 | Dry | Dry |
| | | Post | Wasteland | — | 5/24 | 0.5 | – | 1 | 2 | 0.0/5.2 | Dry | 0.9/8.4 | Dry | Dry |

compared with untreated check plots indicated some residual effectiveness on most of the plots during early summer, satisfactory control was not obtained throughout the second season on any of the plots.

The species composition of larvae collected in 1958 from plots treated with dieldrin in 1956 and 1957 and from associated check plots is shown in Table 2. Only *Aedes dorsalis* was collected from one plot treated in 1956, suggesting tolerance of this species to the failing residual effectiveness of dieldrin. However, the species composition of larvae collected from the remaining dieldrin plots and from associated check plots was not markedly different, indicating no over-all species tolerance to failing insecticide residuals of dieldrin.

In the further larviciding trials made in 1958, the granular materials used were 8/20 mesh bentonite containing 2.5 percent dieldrin, 15/30 mesh attaclay containing 5 percent heptachlor, and 30/60 mesh attaclay containing 10 percent DDT. Plots ranging in size from 0.1 to 0.69 acre were treated between April 29 and June 7, 1958. Crank-type spreaders were used in applying the granules. To facilitate uniform coverage, operators of the spreaders were guided by flagged stakes placed at 20-foot intervals along two sides of the plots. The stakes also assisted in measuring the areas treated. Granules were applied in amounts to give the following dosages of toxicant per acre: 0.25 and 0.12 pound dieldrin; 0.75 and 0.25 pound heptachlor; and 1.5 and 0.75 pound DDT.

The treated plots were flooded from 1 to 5 times during the season. When flooded, both treated and untreated check plots were sampled for mosquito larvae twice each week as in previous larviciding experiments. Samples of mature larvae, when present, were collected for identification.

The results from individual plots treated with dieldrin, heptachlor, and DDT in 1958 are presented in Tables 3, 4, and 5.

Since mosquito production occurred during the season on the majority of the plots, the average numbers of mature larvae and pupae per dip for treated plots are shown together with the concurrent averages for untreated check plots.

Mosquito production varied widely on replicate plots of different habitat types, particularly on seepage areas as compared with plots representing other habitat types.

TABLE 2.—Species composition of mature larvae from 1956 and 1957 dieldrin larvicidal plots and untreated check plots Chinook, Montana, 1958

| Location of plot | Type plots | Number of plots | Number of larvae identified | Percentage for each species by plot location | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Aedes dorsalis* | *Aedes vexans* | *Aedes nigro-maculis* | *Culiseta inornata* | *Culex tarsalis* | Other species* |
| Alfalfa Field | Treated | 1 | 52 | 100 | 0 | 0 | 0 | 0 | 0 |
| | Check | 1 | 109 | 30 | 24 | 46 | 0 | 0 | 0 |
| Pasture | Treated | 4 | 139 | 35 | 16 | 42 | 1 | 6 | 0 |
| | Check | 2 | 132 | 49 | 9 | 29 | 6 | 6 | 1 |
| Bluejoint Meadow | Treated | 3 | 6 | 17 | 17 | 17 | 16 | 0 | 33 |
| | Check | 2 | 67 | 52 | 16 | 6 | 6 | 5 | 15 |
| Roadside Ditch | Treated | 3 | 82 | 75 | 7 | 17 | 1 | 0 | 0 |
| | Check | 3 | 104 | 48 | 24 | 23 | 0 | 5 | 0 |
| Wasteland | Treated | 3 | 7 | 14 | 72 | 14 | 0 | 0 | 0 |
| | Check | 2 | 45 | 11 | 11 | 7 | 27 | 40 | 4 |
| All Plots | Treated | 14 | 286 | 39 | 12 | 44 | 1 | 3 | 1 |
| | Check | 10 | 457 | 41 | 17 | 26 | 5 | 8 | 3 |
| Totals | Both | 24 | 743 | 40 | 15 | 33 | 4 | 6 | 2 |

* Other species include *Aedes idahoensis, A. spenceri, A. trivittatus* and *Anopheles earlei.*

TABLE 3.—Results of residual larviciding experiments with granular dieldrin applied at 0.25 pound and 0.12 pound toxicant per acre Chinook, Montana, 1958

| Pre- or post flood | Location of plot | Date treated | Size of area treated (acre) | Actual dosage lb./acre | Days to first post-treatment flooding | Number of floodings | Average number of mature larvae and pupae per dip on treated plots and untreated check plots | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | May | June | July | August | September |
| | Bluejoint Meadow | 5/7 | 0.51 | 0.25 | 8 | 2 | 0.8/5.2 | Dry | 0.0/0.7 | Dry | Dry |
| Pre | Bluejoint Meadow | 5/8 | 0.41 | 0.24 | 7 | 2 | 0.1/5.2 | 0.1/1.6 | Dry | Dry | Dry |
| | Seepage Area | 5/8 | 0.19 | 0.26 | 11 | 3 | 0.0/53.0 | 0.0/0.7 | 0.0/0.2 | 0.0/0.0 | 0.0/0.0 |
| | Bluejoint Meadow | 5/13 | 0.27 | 0.23 | – | 5 | 0.2/30.0 | 0.0/1.8 | 0.0/7.5 | 2.9/8.4 | 44.2/49.3 |
| | Pasture | 5/27 | 0.48 | 0.26 | – | 2 | 0.2/15.0 | 0.0/2.0 | 0.0/6.1 | 0.0/1.8 | Dry |
| Post | Pasture | 6/5 | 0.20 | 0.25 | – | 1 | — | 25.0P/10.5 | Dry | Dry | Dry |
| | Wasteland | 6/2 | 0.10 | 0.26 | – | 3 | — | 4.2P/13.0 | 0.1/7.4 | 0.0/48.0 | Dry |
| | Seepage Area | 5/29 | 0.10 | 0.26 | – | 3 | — | 0.0/6.6 | 0.0/1.4 | 0.0/0.5 | 0.1/1.4 |
| | Bluejoint Meadow | 5/7 | 0.45 | 0.11 | 8 | 3 | 18.7/25.0 | 0.1/0.4 | 0.1/0.7 | Dry | Dry |
| | Pasture | 5/9 | 0.22 | 0.11 | 31 | 3 | Dry | 3.2/7.1 | 0.6/2.0 | Dry | 6.7/9.1 |
| Pre | Pasture | 5/9 | 0.41 | 0.12 | 26 | 2 | Dry | 4.7/11.0 | Dry | Dry | 0.8/0.2 |
| | Wasteland | 5/7 | 0.51 | 0.12 | 19 | 2 | 31.8*/21.4 | 3.9/10.6 | Dry | 6.3/12.6 | Dry |
| | Seepage Area | 5/8 | 0.10 | 0.12 | 13 | 1 | 0.0/0.8 | 0.1/1.6 | 0.0/0.1 | 0.0/<0.05 | 0.0/0.0 |
| | Bluejoint Meadow | 5/15 | 0.37 | 0.10 | – | 2 | 0.0/25.0 | 0.1/1.0 | 0.0/0.1 | Dry | Dry |
| | Pasture | 6/3 | 0.10 | 0.12 | – | 1 | — | 0.0/1.7 | 0.0/2.9 | Dry | Dry |
| Post | Pasture | 6/4 | 0.40 | 0.12 | – | 2 | — | 0.0/60.0 | 1.1/7.6 | Dry | Dry |
| | Wasteland | 5/13 | 0.41 | 0.12 | – | 5 | 0.0/30.0 | 0.0/2.0 | 0.0/7.8 | 0.6/8.4 | 0.1/49.3 |
| | Seepage Area | 5/29 | 0.10 | 0.13 | – | 3 | — | 0.0/6.6 | 0.0/1.44 | 0.0/0.45 | 0.0/1.4 |

P = Pupae only.

* Includes pupae, days after flooded, thus obviously washed into this deep swale.

TABLE 3. Results of residual larviciding experiments with granular heptachlor applied at 0.75 pound and 0.25 pound toxicant per acre Chinook, Montana, 1958

| Pre- or post flood | Location of plot | Date treated | Size of area treated (acre) | Actual dosage lb./acre | Days to first post-treatment flooding | Number of floodings | Average number of mature larvae and pupae per dip on treated plots and untreated check plots | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | May | June | July | August | September |
| | Bluejoint Meadow | 5/6 | 0.41 | 0.73 | 13 | 3 | 0.0/9.4 | 0.0/1.65 | 0.7/1.2 | Dry | Dry |
| | Pasture | 5/6 | 0.69 | 0.72 | 20 | 3 | 2.9/15.0 | Dry | 4.7/28.4 | Dry | Dry |
| Pre | Wasteland | 5/5 | 0.58 | 0.70 | 21 | 5 | 3.2/15.0 | 0.0/10.6 | 2.5/52.4 | Dry | Dry |
| | Wasteland | 4/30 | 0.43 | 0.82 | 33 | 4 | Dry | 0.1/2.3 | 0.1/1.2 | 3.7/6.6 | Dry |
| | Seepage Area | 5/1 | 0.10 | 0.75 | 26 | 2 | 0.0/53.0 | 0.0/61.0 | 0.0/4.6 | 0.3/1.1 | 0.0/2.8 |
| | Bluejoint Meadow | 5/14 | 0.26 | 0.77 | – | 2 | 0.0/1.4 | 0.0/1.2 | Dry | Dry | Dry |
| | Pasture | 5/10 | 0.38 | 0.79 | – | 1 | 0.0/5.5 | Dry | Dry | Dry | Dry |
| Post | Pasture | 6/6 | 0.42 | 0.72 | – | 3 | — | 3.5/94.0 | 6.2/97.0 | 9.2/31.0 | Dry |
| | Wasteland | 5/10 | 0.39 | 0.77 | – | 2 | 0.0/7.7 | 0.0/7.5 | Dry | 0.0/0.0 | Dry |
| | Seepage Area | 5/14 | 0.10 | 0.75 | – | 4 | 0.0/0.0 | 0.0/6.0 | 0.1/8.6 | 0.1/0.2 | 0.0/2.8 |
| | Bluejoint Meadow | 5/8 | 0.50 | 0.25 | 7 | 3 | 0.0/5.2 | 3.4/1.1 | 0.0/1.2 | Dry | Dry |
| | Bluejoint Meadow | 5/8 | 0.55 | 0.24 | 7 | 3 | 0.0/5.2 | 0.0/0.7 | 0.0/1.2 | Dry | Dry |
| Pre | Pasture | 4/30 | 0.52 | 0.24 | 30 | 5 | 0.0/2.0 | Dry | 11.0/54.0 | 8.7/7.2 | 1.4/7.2 |
| | Wasteland | 5/1 | 0.47 | 0.26 | 14 | 4 | 0.0/0.9 | Dry | 0.2/0.2 | 1.8/0.9 | Dry |
| | Seepage Area | 5/1 | 0.10 | 0.25 | 26 | 1 | 0.1/53.0 | 0.7/12.0 | 0.8/2.6 | 5.3/1.1 | 3.4/2.8 |
| | Bluejoint Meadow | 5/15 | 0.40 | 0.25 | – | 1 | 0.0/5.2 | Dry | Dry | Dry | Dry |
| | Pasture | 5/10 | 0.20 | 0.25 | – | 2 | 0.0/28.0 | 0.0/2.9 | Dry | 3.6/16.4 | 0.0/0.0 |
| Post | Pasture | 6/4 | 0.18 | 0.27 | | 2 | — | 0.8/9.5 | 0.0/5.2 | Dry | Dry |
| | Wasteland | 6/4 | 0.58 | 0.26 | – | 2 | — | 2.6/13.7 | 0.2/9.0 | 0.1/0.4 | 0.1/0.2 |
| | Wasteland | 6/7 | 0.49 | 0.25 | – | 1 | — | 0.0/1.7 | 0.0/2.9 | Dry | Dry |
| | Seepage Area | 6/5 | 0.30 | 0.25 | – | 2 | — | 0.0/5.9 | 1.3/17.8 | 0.3/9.4 | Dry |
| | Seepage Area | 6/5 | 0.10 | 0.25 | – | 4 | — | 0.2/5.8 | 0.0/17.8 | 0.0/7.4 | Dry |

TABLE 5.—Results of residual larviciding experiments with granular DDT applied at 1.5 pounds and 0.75 pound toxicant per acre Chinook, Montana, 1958

| Pre- or post flood | Location of plot | Date treated | Size of area treated (acre) | Actual dosage lb./acre | Days to first post-treatment flooding | Number of floodings | Average number of mature larvae and pupae per dip on treated plots and untreated check plots | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | May | June | July | August | September |
| Pre | Bluejoint Meadow | 4/30 | 0.49 | 1.52 | 15 | 2 | 2.6/5.2 | 1.0/510.0 | Dry | Dry | Dry |
| | Bluejoint Meadow | 4/29 | 0.30 | 1.50 | 26 | 2 | Dry | 39.7/27.0 | 20.1/25.2 | Dry | Dry |
| | Pasture | 5/10 | 0.41 | 1.46 | 107 | 1 | Dry | Dry | Dry | Dry | 0.1/2.9 |
| | Wasteland | 5/1 | 0.37 | 1.90 | 30 | 3 | Dry | 0.6/4.5 | 0.2/0.7 | 16.0/8.5 | 6.6/7.2 |
| Post | Bluejoint Meadow | 5/10 | 0.26 | 1.50 | — | 3 | 0.0/5.2 | 0.0/5.0 | 0.0/1.2 | Dry | Dry |
| | Pasture | 5/27 | 0.40 | 1.50 | — | 3 | 5.9*/9.6 | 0.0/0.9 | 0.0/8.2 | 0.0/2.4 | — |
| | Wasteland | 5/28 | 0.27 | 1.45 | — | 4 | — | 0.0/0.1 | 0.1/2.5 | 1.2/16.7 | Dry |
| Pre | Bluejoint Meadow | 4/30 | 0.51 | 0.68 | 15 | 1 | 25.3/25.0 | Dry | Dry | Dry | Dry |
| | Pasture | 4/29 | 0.20 | 0.73 | 31 | 2 | Dry | 11.0/13.6 | 89.4/44.0 | Dry | Dry |
| | Pasture | 5/9 | 0.12 | 0.80 | 20 | 4 | Dry | 1.1/4.5 | Dry | 0.3/0.8 | Dry |
| | Wasteland | 5/3 | 0.41 | 0.73 | 11 | 3 | 2.7/4.1 | Dry | 15.4/48.8 | 4.1/1.8 | Dry |
| Post | Bluejoint Meadow | 5/14 | 0.27 | 0.77 | — | 2 | 21.0/25.0 | 0.3/0.35 | Dry | Dry | Dry |
| | Pasture | 5/27 | 0.46 | 0.76 | — | 3 | 0.6*/9.6 | 0.5/5.1 | 0.0/8.2 | Dry | 10.7/43.0 |
| | Wasteland | 5/15 | 0.12 | 0.81 | — | 3 | 0.0/10.8 | 0.0/19.5 | 0.1/0.1 | Dry | Dry |

* Pupae only.

Seepage areas typically were relatively small accumulations of water near major irrigation canals. Entire areas of such isolated seepage water were usually treated. Both dieldrin and heptachlor, even at the lower dosage rates, generally were effective on these small areas of quiet water (Tables 3 and 4). On the other hand, evidence of failure for both these toxicants, even at the higher dosages, occurred on some plots located on bluejoint meadows and pastures. These "on-field" plots usually represented minor portions of relatively large areas which were subject to flooding.

Some of the sites selected for preflood treatment were later found to be in the path of flowing, shallow water during irrigations. Insecticidal failures on these plots suggested that flow through the plots at higher water levels caused dissipation of the insecticidal residues. In addition, some of the indicated failures early in the season may have been partially due to larvae and pupae that were transported into the plots during floodings. This was particularly evident for plots where mosquito production was markedly reduced later in the season when the levels of irrigation water were more stabilized.

Two of the three 1958 post-flood DDT treatments at 1.5 pounds toxicant per acre gave effective control throughout the season (Table 5). The third plot showed considerable evidence of DDT residue during most of the season. All of the other DDT treatments showed little or no residual effectiveness. Mosquito production was persistently high on the plots that received preflood DDT treatments, even at 1.5 pounds toxicant per acre, suggesting that exposure to the elements caused the DDT to deteriorate during the dry periods prior to flooding of the plots.

Both dieldrin and heptachlor treatments were generally more effective than DDT, except for the post-flood applications of DDT at 1.5 pounds per acre as noted above (Tables 3 and 4). Some of the erratic results obtained with dieldrin and heptachlor at the lower dosages may have been partly due to uneven coverage in these scanty applications.

TABLE 6.—Species composition of mature larvae from larvicidal plots and untreated check plots Chinook, Montana, 1958

| Insecticide and dosages (lb. toxicant/A) | Plot location | No. of plots | No. of larvae identified | Percentage for each species by plot location | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Aedes dorsalis* | *Aedes vexans* | *Aedes nigromaculis* | *Culiseta inornata* | *Culex tarsalis* | Other species* |
| Dieldrin 0.5 lb. and 0.25 lb. per acre | Blue joint Meadow | 5 | 154 | 51 | 5 | 43 | 0 | 0 | 1 |
| | Pasture | 4 | 129 | 23 | 36 | 33 | 1 | 5 | 2 |
| | Wasteland | 2 | 134 | 58 | 18 | 1 | 11 | 10 | 2 |
| | Seepage Area | 1 | 5 | 80 | 0 | 0 | 20 | 0 | 0 |
| Heptachlor 0.25 lb. and 0.75 lb. per acre | Bluejoint Meadow | 2 | 17 | 100 | 0 | 0 | 0 | 0 | 0 |
| | Pasture | 4 | 134 | 64 | 22 | 8 | 1 | 5 | 0 |
| | Wasteland | 4 | 156 | 27 | 23 | 46 | 1 | 2 | 1 |
| | Seepage Area | 5 | 354 | 8 | 4 | 0 | 2 | 85 | 1 |
| DDT 0.75 lb. and 1.5 lb. per acre | Bluejoint Meadow | 4 | 156 | 62 | 15 | 1 | 13 | 0 | 9 |
| | Pasture | 5 | 177 | 64 | 7 | 27 | 1 | 0 | 1 |
| | Wasteland | 4 | 167 | 25 | 11 | 20 | 19 | 23 | 2 |
| Untreated Check Plots | Bluejoint Meadow | 6 | 226 | 39 | 7 | 43 | 0 | 9 | 2 |
| | Pasture | 15 | 574 | 60 | 17 | 15 | 1 | 5 | 2 |
| | Wasteland | 11 | 732 | 35 | 27 | 9 | 6 | 21 | 2 |
| | Seepage Area | 4 | 454 | 44 | 5 | 1 | 17 | 32 | 1 |

* Includes 27 *Aedes idahoensis*, 12 *A. trivittatus*, 9 *A. spenceri*, 4 *A. flavescens*, 1 *A. riparius*, 1 *A. sticticus*, and 11 *Anopheles earlei*.

The species composition of larvae collected from plots treated in 1958 and from untreated check plots is shown in Table 6. Here again, 4 of 5 larvae from a dieldrin plot were *A. dorsalis,* and 17 larvae from a heptachlor plot were exclusively *A. dorsalis.* On the basis of the comparatively small numbers of larvae collected from these two plots, the predominance of *A. dorsalis* suggests a tolerance of this species to residuals of dieldrin and heptachlor. However, the species composition of the considerably larger numbers of larvae from the remaining larvicidal plots was not significantly different from that of untreated check plots. Thus there was no marked evidence of species tolerance to insecticide residuals of dieldrin, heptachlor, or DDT.

In summary, the results of the 1958 larviciding trials indicate that preflood applications of dieldrin at the rate of 0.25 pound toxicant per acre and post-flood applications of DDT at 1.5 pounds per acre provided almost complete control of irrigation mosquitoes for the entire season. Post-flood treatments with dieldrin at 0.25 pound per acre and heptachlor at 0.75 pound per acre provided effective control for about 12 weeks. Heptachlor applied as a preflood treatment at 0.75 pound per acre provided effective mosquito control for at least 9 weeks.

## SUMMARY

Single preflood and post-flood applications of dieldrin, heptachlor and DDT as water emulsions and granular formulations at approximately 1.0, 1.5, and 3.0 pounds toxicant per acre, respectively, did not provide satisfactory control of irrigation mosquitoes during the third season after treatment; and granular dieldrin at 0.5 lb./acre did not provide complete control throughout the second season. Preflood applications of granular dieldrin at 0.25 lb./acre and post-flood applications of granular DDT at 1.5 lb./acre gave almost complete control throughout one season. Post-flood dieldrin at 0.25 lb./acre and granular heptachlor at 0.75 lb./acre provided effective control for about 12 weeks. Preflood heptachlor at 0.75 lb./acre was effective for at least 9 weeks.

Dieldrin and heptachlor were more effective on seepage areas of quiet water than on pastures and bluejoint meadows which were subject to repeated floodings by irrigation. On relatively small seepage areas, granular dieldrin at 0.12 lb./acre provided almost complete control throughout one season, and granular heptachlor at 0.25 lb./acre was effective for 7 weeks applied preflood and for 11 weeks applied post-flood.

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# A MOSQUITO LIGHT TRAP FOR USE ON CESSPITS

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Various methods for investigations into the habits of mosquitos or for their control are based on their phototropism.

In Israel, about thirty-six years ago experiments were carried out by us and the following observations made:

1. In barns we sealed all cracks and covered with sacks all entrances and windows except the lower part of the doorway. Here we placed a glass box having an open back which faced the room. All the inside surfaces of the other sides of the box were smeared with castor-oil. At the furthest corner of the room, a smoke was generated. The mosquitoes escaped from the smoke into the single light source, namely, the glass box and stuck to the walls.

2. Our observations show that at dusk, which in Israel lasts about twenty minutes only, the mosquitoes begin to move and stream towards light.

We made use of this phenomenon and closed all doors and windows of a room and darkened it further with sacks or blankets, except for one window which remained closed but uncovered.

The mosquitoes in the room, attracted to the light outside, moved at dusk towards the window and were lightly crushed by hand against the glass, counted and identified.

3. The above mentioned observation (2) gave us the idea of using this method for easily trapping and identifying mosquitoes in a room at other hours of the day.

A room was prepared as outlined above and sprayed very lightly here and there with a small perfume spray consisting of an alcoholic extract of pyrethrum at a very low concentration.

This excited the mosquitos to leave their resting places and to escape towards the light source, the single uncovered window, where they could be lightly crushed and identified.

4. Today we use wooden boxes affixed to the ceiling on a semi-dark, non draught corner. The lower half of the front wall of the box is open. The weak light and the more even temperature and humidity inside the boxes offer the mosquitoes better resting conditions than in the rest of the room and they concentrate there. From the boxes they are easily recovered and identified.

The use of traps affixed to windows for trapping mosquitoes is widespread throughout the world and no description is needed here.

Recently, we were interested in beginning observations on the habits of *Culex pipiens molestus* mosquitoes breeding in cesspits in enormous numbers.

Many years ago, one practice in Israel was to kill the adults there by a primitive method, namely, by inserting a kerosene-impregnated rag set on fire, within the cesspits. However, as the cesspit was not completely air tight at the surface, many mosquitoes escaped. This gave us the idea, that a very light smoke within the cesspit would drive the mosquitoes out and if a trap were to be set over the opening of the cesspit, the mosquitoes would be trapped. We found that a standard type mosquito cage was not suitable for this purpose.

We therefore began to use a modified fly trap of the cone type which has so far given excellent results. The diagram of the trap is attached herewith and full particulars are shown thereon (Figure 1).

Note, that this trap differs from the standard fly cone trap in the following respects;

(1) The base is solid sheet metal extending beyond the side. The opening

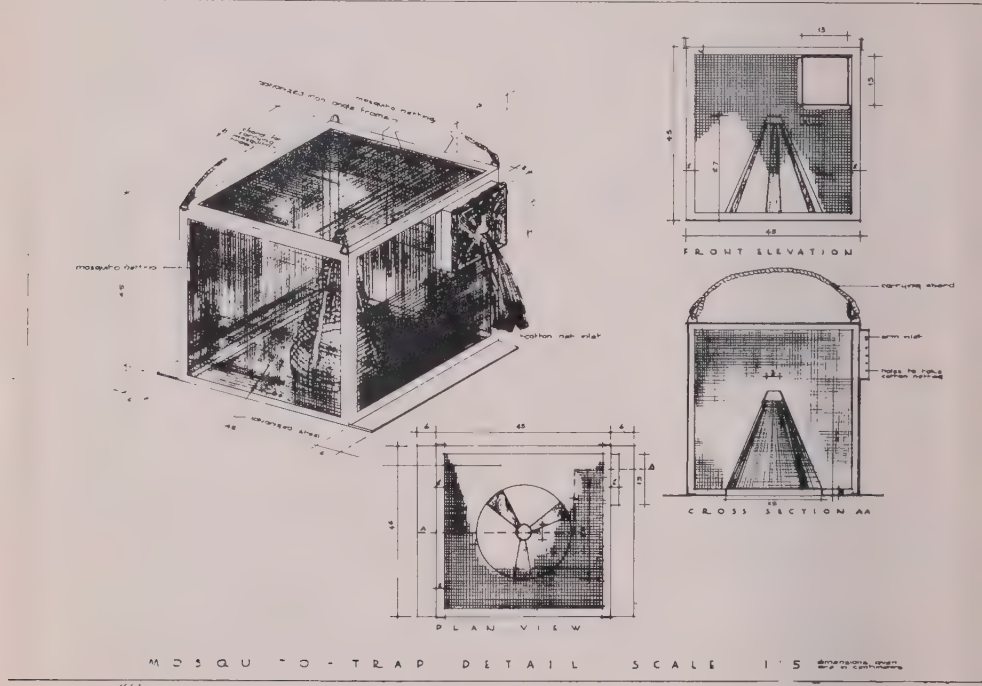


FIG. 1.—Details of mosquito trap:

giving entrance to the cone and admitting light is in the centre of this base. Even better results were obtained by using a wider cone than the one described on the diagram. This larger cone measures 30 x 25 x 2.5 cm.

(2) The upper corner of one of the walls has an arm-inlet through which a large glass suction tube can be inserted for removing the mosquitos.

This trap is placed over the opening of the cesspit during the daylight hours, beginning from about one hour after sunrise. Large numbers of mosquitoes are attracted to the light, enter into the trap and cannot escape. To what extent the use of smoke would increase the catch, awaits further observations.

## SUMMARY

1. Some practical methods of trapping adult mosquitos for survey purposes are given.

2. A method of trapping adult mosquitos breeding in cesspits, by means of a light trap, a modified fly trap of the cone type, is described.

3. Details of the trap are given and shown in a diagram.

# OBSERVATIONS ON THE WORLD HEALTH ORGANIZATION ADULT TEST KIT FOR BIOASSAY OF INSECTICIDE DEPOSITS ON WALL SURFACES

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Introduction. The use of bioassay tests in insecticide trials and in control schemes has enabled much extra and extremely useful information to be obtained. However, up to the present there has been no standard technique for carrying out such tests, and each entomologist has either developed his own methods or made use of previously known methods. As with the adult mosquito test kit, the Expert Committee on Insecticides (1957) felt that much more information could be made available if a standard wall test kit was put into use. The majority of bioassay tests had been carried out with apparatus based on either a three-inch diameter glass funnel or an eleven-centimeter petri dish (Burnett, 1957; Davidson, 1950; Hocking *et al.*, 1959); the two chambers supplied by the World Health Organization were of approximately the same dimensions. These chambers were supplied to several different research organizations with the request that their merits and faults should be assessed.

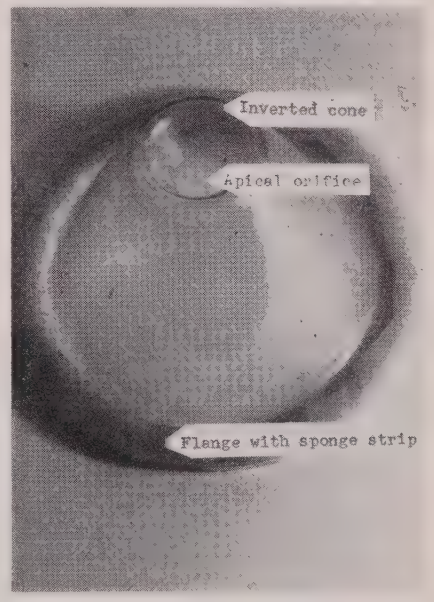


Fig. 1.—The World Health Organization Cone exposure chamber.

The conical exposure chamber (Figure 1) was constructed of plastic with a flange around the mouth and in place of the stem of the funnel there was an inverted conical orifice through which the mosquitoes could be introduced. With the funnels was supplied adhesive-backed plastic strip to be used to plug gaps between the funnel and the wall surface. When in use the chamber was to be fixed to the test surface and the mosquitoes blown in through the orifice by means of a straight tube. The purpose of the inverted conical orifice was to reduce the chances of an insect flying back out of the opening. At the end of the exposure time a bent sucking tube could then be reinserted through this opening and the mosquitoes removed to a holding cage.

The dish exposure chamber (Figure 2) also of plastic, was in two sections. The base section had a turned lip along the top and bottom edges and a centrally placed opening eight centimeters in diameter. The top section was an eight-centimeter dish approximately one centimeter deep with a squared flange so made that it would slide into the base under the two

turned lips. A set of cardboard shutters was also provided. To assemble the apparatus, the dish was slid into the base and a cardboard shutter inserted between the dish and the base. A small hole towards one end of the shutter permitted mosquitoes to be blown into the chamber by means of a straight tube, after which the shutter was then adjusted to block the hole. The complete exposure chamber was then fastened to the wall surface and at the start of the exposure time the shutter was removed, at the end of the exposure time the shutter was reinserted and the insects isolated within the chamber. The complete apparatus was then removed and the mosquitoes transferred to a suitable holding cage.

A sucking tube was also provided with the kit; it consisted of a rubber tube with a mouthpiece, a one-by-three-inch chamber and a one-quarter-inch diameter tube with an angled tip.

The wall exposure chambers were received with a request to carry out an investigation along the following lines:—

(1) The relative convenience of handling the two types in the field.
(2) The consistency of results obtained with each type of exposure chamber when replicate exposures are made (i.e. more than one test performed on the same wall surface).
(3) A comparison of results obtained with the two types of exposure chamber when applied to the same type of wall surface. (In the evaluation of results, control as well as test mortalities should be taken into account.)
(4) Which of the two methods indicate the aging of insecticide deposits with the greater degree of accuracy.

It was also suggested that, "observations be made over a period of six months and

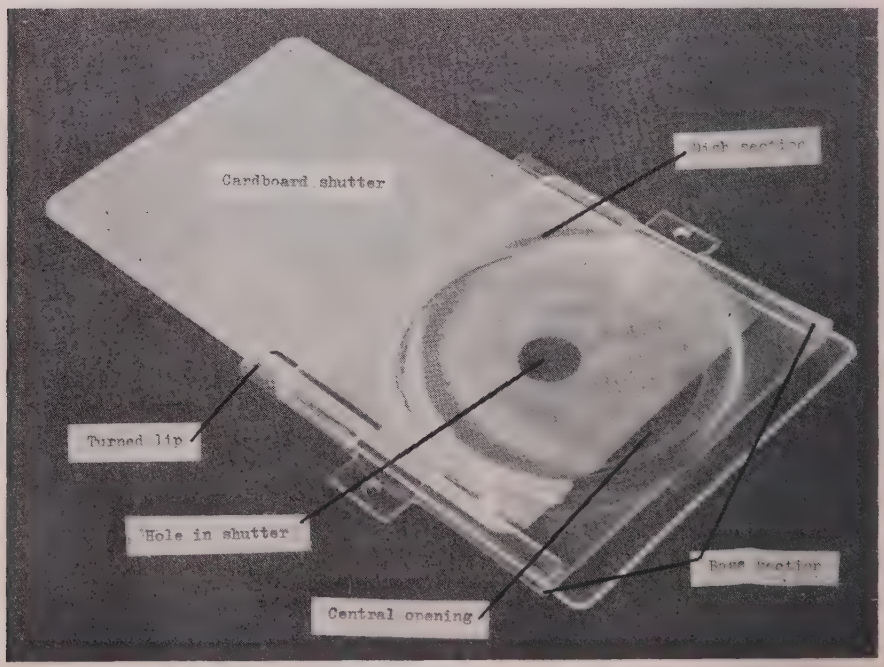


FIG. 2.—The World Health Organization Dish exposure chamber.

that exposures be carried out (a) twice weekly for the first three months, and (b) monthly for the second three months on walls sprayed with DDT at a dosage of 2 gm. per sq.m. and dieldrin at 0.5 gm. per sq.m. Both sorbtive (mud) and non-sorbtive surfaces (material to be stated) to be used if possible and data on the sorbtive character of the wall to be provided with the report."

Methods. In order to carry out all phases of the work a series of tests were carried out both at the Colonial Pesticides Research Unit laboratory in Arusha, and at the field station at Magugu, 93 miles southwest of Arusha. The observations for section (1) were obtained from tests carried out in the experimental houses and in native houses at Magugu. To provide a wall surface on which to carry out tests for sections (2), (3) and (4) a brick wall plastered with sorbtive and non-sorbtive mud was constructed at Arusha. The wall was built around the inside of a circular aluminum house (Uniport Altent). The wall, 5 feet 9 inches (178 cm) high and about 20 feet (5 metres) long was divided into two sections, one plastered with a sorbtive mud (from an area near Magugu) and the other with a non-sorbtive mud from Njoro Nkubwa near Taveta used previously by Burnett (1957). Before being sprayed, each section was divided into two identical panels each 2.15 square metres in area which were marked on a grid system and coded so that each square possessed a reference letter and number. The space between each pair of panels was to be left unsprayed and to be used as a control surface. When the wall was plastered it was intended to have the muds about one inch thick, but unfortunately this was not possible and the plaster was only about half an inch thick.

The panels were sprayed with an Oxford Precision sprayer, fitted with a number zero flat-fan nozzle, at a nozzle pressure of 30 lbs per square inch. One panel of each type of mud was sprayed with DDT at an intended dosage of 2.0 gms per sq. metre, and the other panel of each type of mud was sprayed with dieldrin at an intended dosage of 0.5 gm per sq. metre. During the spraying, each control panel was shielded to prevent contamination. The required weight of the wettable powder was mixed with one litre of water and each panel was sprayed using vertical swathes. When a panel had been coated once (three swathes), the operator paused to permit the water to soak into the mud, and then repeated the cycle until the whole of the spray mixture was applied to the wall. The spray apparatus was rinsed with water between the application of the DDT and the dieldrin wettable powders. For chemical estimation of the spray deposit three sample papers were fixed to each panel prior to the application of the insecticide. These papers were analysed by the chemistry department using the Stepanow reduction method for total chlorine estimation. The mean deposit on each panel was found to be: DDT on sorbtive mud, 1.98 gms per sq. m.; DDT on non-sorbtive mud, 1.69 gms per sq. m.; dieldrin on sorbtive mud 0.63 gm per sq. m.; and on non-sorbtive mud 0.59 gm per sq. m.

Various methods of fastening the exposure chambers to wall surfaces were tried and it was found that for exposures on solid wall surfaces four pieces of cellotape $\frac{5}{8}$ inch (1.5 cm) wide by 6 inches (15 cm) long were sufficient to hold the conical chamber in place and two such pieces would hold the dish chamber in place.

The test insects were adult female *Anopheles gambiae* and adult female *Aedes aegypti,* each maintained as a colony at the laboratory. The *A. gambiae* colony originated from the East African Institute of Malaria at Amani (Shute, 1956). The *A. aegypti* colony is a mixed strain which has been maintained at this Unit for several years. In all tests the insects were exposed for a thirty-minute period, three hours after the blood-meal. Whenever possible only three-day-old mosquitoes were used in the tests, but unfortunately it was at times necessary to use mosquitoes up to six days old that might be gravid or unfed. When the insects were exposed to the

DDT-treated surface, it was noticed that they became excited after a few minutes (Kennedy, 1947; Davidson, 1953) and if more than 20 insects were inserted in the conical chamber the exposure time was frequently lengthened in the attempts to remove the last few. For this reason all tests with the cone and dish chambers on DDT and dieldrin-treated surfaces were set up with an average of 15 mosquitoes per chamber.

The holding cages were 6" x 3" x 3" (15 x 7.5 x 7.5 cm.) wire frame cages covered with mosquito net. To transfer the mosquitoes from the conical exposure chamber to the holding cage, a long, straight sucking tube with an angled tip, but without a central chamber, was found to be most efficient. The mosquitoes were sucked out of the chamber and blown gently into the holding cage. With the dish exposure chamber, the method suggested in the instructions was employed, "the exposure chamber is taken from the wall and placed over the top of a half-pint disposable paper cup. The cardboard slide is then removed carefully, thus letting the mosquitoes pass into the paper cup which will serve as recovery cage during the following 24 hours," except that in place of the cup a wire holding cage was used. It was found that although one person could do the job, it was more easily done if there was an assistant. A piece of cotton wool soaked in sugar solution was placed on top of the net of each cage, and the cages were placed in a darkened cupboard at a relative humidity of 70–90 percent and a temperature of 21 ± 3° C. for a twenty-four hour holding period after which the mortality count was taken. Any mosquito that could not fly up off the bottom and rest on the sides or top of the cage was counted as dead. After the mortalities were recorded the cages were dismantled, washed in soap and water, rinsed and then dried; at no time was there any sign of contamination of the frames or nets. On completion of each series of tests the exposure chambers were also washed in the same manner and the cardboard slides were wiped with a damp cloth.

The apical hole of the conical exposure chamber became torn and enlarged after repeated use, and when mosquitoes were observed flying out of the hole a group of tests were set up with 20 *A. aegypti* in each of ten cone chambers. The exposure chambers were set in a vertical position against filter papers treated with a 0.05 percent dieldrin-risella oil solution. At the end of a thirty-minute exposure time the mosquitoes remaining in the cones were counted. In only one cone were there still twenty mosquitoes and in two of the chambers half the mosquitoes had escaped. In the control chamber (non-insecticidal oil-treated paper) 30 percent of the insects had escaped. The average number escaped from the ten chambers was 33 percent. With practice, it was possible to insert enough wool to block the hole and yet provide the minimum non-lethal surface on which the insects might rest. The first series of comparison tests with the dish and the cone showed that there was no difference between the two, and in order to check the effect of plugging the orifice of the cone, a test was set up in which *A. aegypti* were exposed, in the plugged cone, and the dish, to filter papers impregnated with an 0.05 percent dieldrin-risella oil solution. The mosquitoes were exposed for a thirty-minute period and twenty-four hours later the mortality counts were taken. There was no difference in the mortalities obtained with the plugged cone and the dish, and since the unplugged cone and the dish were already known to give similar results, all further tests with the cone were carried out with the orifice plugged.

## OBSERVATIONS

### 1. The Convenience of Handling the Two Types of Exposure Chamber in the Field

The main observations from the field experiments were that the wall of the average native house was so badly cracked and uneven that it was impossible to carry out a test. In the case of the dish exposure

chamber, if the wall surface was rough or uneven, any method of plugging the gaps between the chamber and the wall surface resulted in the chamber being so far from the wall that on reinserting the shutter it passed over the insects and trapped them between the shutter and the wall rather than within the chamber. On a smooth surface, when a series of exposures were required, the dish chamber had the advantage that it could be closed on schedule and removed at leisure for transfer of the insects to the recovery cages. Thus any problems in transferring the insects from the chamber to the holding cage did not result in an increased exposure time. The conical exposure chamber could be affixed to any type of surface and plugging the gaps between the chamber and the surface did not interfere with the test. Exposure tests have been carried out using the conical chamber to confine insects on treated thatch. The conical chambers could be loaded readily, a straight tube was found to be the most efficient method of getting the insects into the chambers. For removing the insects, the angled end section of the sucking tube provided with the kit was used, and with this the mosquitoes could be removed 5–10 at a time to the holding cage.

In the first series of experiments it was not necessary to save the wall surface for future tests and the chambers were nailed to the wall; later, when it was desirable to save the surfaces for future tests cellotape was used. When using cellotape it is essential to place the replicates on exactly the same spot since the cellotape will have stripped insecticide off the mud.

2. The Consistency of Results Obtained with Each Type of Exposure Chamber When Replicate Exposures Are Made

The results of this series of tests are shown in Tables 1 and 2. In each series there are eight replicates, plus a control where shown, with an average of 15 insects each. The mortalities recorded are the control mortalities, and mean experimental mortalities corrected for control deaths by application of Abbott's formula (Finney, 1952), with their standard deviations. These tests were carried out six months after treatment of the mud surfaces (at the completion of the wall exposure series), and for this reason the *A. aegypti* exposure time was extended to 60 minutes while the *A. gambiae* exposure time remained unchanged at 30 minutes. It is the authors' opinion that there would have been less variations among the replicates if the exposure time had been extended even more (2–3 hours for *A. aegypti* and 1 hour for *A. gambiae*).

With the small number of insects per replicate (an average of 15), there was a wide variation in the mortalities and with the too short exposure period this resulted in a correspondingly high variance among replicates. Thus we have a range of mortalities of from zero to 25 percent in one

TABLE 1.—*A. aegypti* exposed for 60 minutes to DDT and dieldrin on sorbtive and nonsorbtive surfaces

| Insecticide | Type of Mud | Exposure chamber | Control mortality | Corrected mean mort. with s.d. | t |
|---|---|---|---|---|---|
| DDT | Sorbtive | Cone | 0 | 4.98 ± 4.42 | t = 0.25 |
| | | Dish | 0 | 4.50 ± 3.02 | |
| | Nonsorbtive | Cone | — | 3.71 ± 5.61 | t = 0.31 |
| | | Dish | — | 4.55 ± 5.34 | |
| Dieldrin | Sorbtive | Cone | 0 | 13.53 ± 9.50 | t = 2.87 |
| | | Dish | 0 | 2.87 ± 4.40 | |
| | Nonsorbtive | Cone | — | 4.43 ± 5.31 | t = 0.02 |
| | | Dish | — | 4.48 ± 4.43 | |

TABLE 2.—*A. gambiae* exposed for 30 minutes to DDT and dieldrin on sorbtive and nonsorbtive surfaces

| Insecticide | Type of Mud | Exposure chamber | Control mortality | Corrected mean mort. with s.d. | t |
|---|---|---|---|---|---|
| DDT | Sorbtive | Cone | 0 | 5.93 ± 4.31 | t = 1.79 |
| | | Dish | 23.1 | 17.89 ± 17.40 | |
| | Nonsorbtive | Cone | — | 21.06 ± 17.90 | t = 0.07 |
| | | Dish | 6.7 | 21.67 ± 9.67 | |
| Dieldrin | Sorbtive | Cone | 6.7 | 10.96 ± 7.17 | t = 0.49 |
| | | Dish | — | 13.02 ± 9.14 | |
| | Nonsorbtive | Cone | 10 | 16.33 ± 7.25 | t = 0.99 |
| | | Dish | 0 | 21.57 ± 12.36 | |

of the series and a similar range in the others. It is for this reason that the standard deviation is frequently equal to, or in some cases larger than, the mean mortality. The tests with *A. gambiae* suffered in a like manner, although with the slightly higher general mortality, not quite to the same extent. The actual mortalities for each replicate may be found in Tables I and II of the mimeographed report circulated by the World Health Organization (Armstrong and Bransby-Williams, 1959).

3. A Comparison of Results Obtained with the Two Types of Exposure Chamber When Applied to the Same Wall Surface

A comparison of the mean mortalities with their standard deviations using the method for determination of significance of difference between means of small samples (Paterson, 1939) was carried out on the data of the cone and dish exposures on each type of treated surface (Tables 1 and 2). The values of "t" obtained are shown in the last column of the tables. For seven degrees of freedom, a value of "t" greater than 2.365 indicates a significant difference at the $P = 0.05$ level. In Table 1 the only significant difference is in the series on dieldrin-treated sorbtive mud ($t = 2.87$). Since one of the standard deviations is of the order of three-quarters of the mean and the other is almost twice the mean, and none of the other tests approach significance we consider this result is due to chance and that there is no real difference in the results obtained with the two types of exposure chambers. Although the other tests all show a large standard deviation when compared to the mean mortality (see previous paragraph), the mean mortalities by themselves are in very close agreement. In Table 2, there is no value of "t" which indicates a difference between the dish and the cone. The very small values of "t," in spite of the large difference in some of the mean mortalities, may be accounted for by the large standard deviations, i.e. in Table 2, for cone versus dish on DDT-treated sorbtive mud, mean mortalities were 5.93 and 17.89 but the standard deviations were 4.31 and 17.40 respectively. As discussed in section 2 above, the variances in the tests were exaggerated by the small number of insects used in each replicate.

4. Comparison of the Two Methods for Demonstrating the Aging of Insecticide Deposits

A series of exposures were carried out comparing the dish and the cone exposure chambers on the different surfaces, over the full twenty-four week period. The results are not shown in this report but they do show that the two methods are equally good in showing the aging of insecticide deposits. The graphs of this series are to

be found in the previous report by Armstrong and Bransby-Williams (1959). These findings were also confirmed by the observations in section 3.

5. Comparison of the Two Methods for Demonstrating the Sorbtive Character of the Walls

In the twice weekly wall exposure series, *A. aegypti* and *A. gambiae* were exposed under cone and dish exposure chambers to DDT- and dieldrin-treated sorbtive and non-sorbtive muds. The weekly mortalities obtained were plotted against time after treatment and graphs drawn to show the loss of efficiency of insecticide deposits. To conserve space only one graph (Figure 3) is shown. This illustrates the mortalities recorded when *A. gambiae* were exposed for thirty minutes to dieldrin-treated sorbtive and non-sorbtive muds. The full series of graphs are shown in the preliminary report (Armstrong and Bransby-Williams, 1959).

Since there was shown to be no difference in the results obtained with the cone and dish exposure chambers, these mortalities were combined, and for the period of weeks 1–12 each point on the graph represents eight replicates of approximately 15 mosquitoes each. For the tests at weeks 16, 20 and 24 there were four replicates of 15 insects each. Throughout the wall exposure series daily temperature and humidity records were kept and the daily rainfall measured. For the whole of this period the mean temperature (degrees Centigrade) was 22.4 with a maximum of 27.2 and a minimum of 18.3, and the mean relative humidity was 75.5 percent

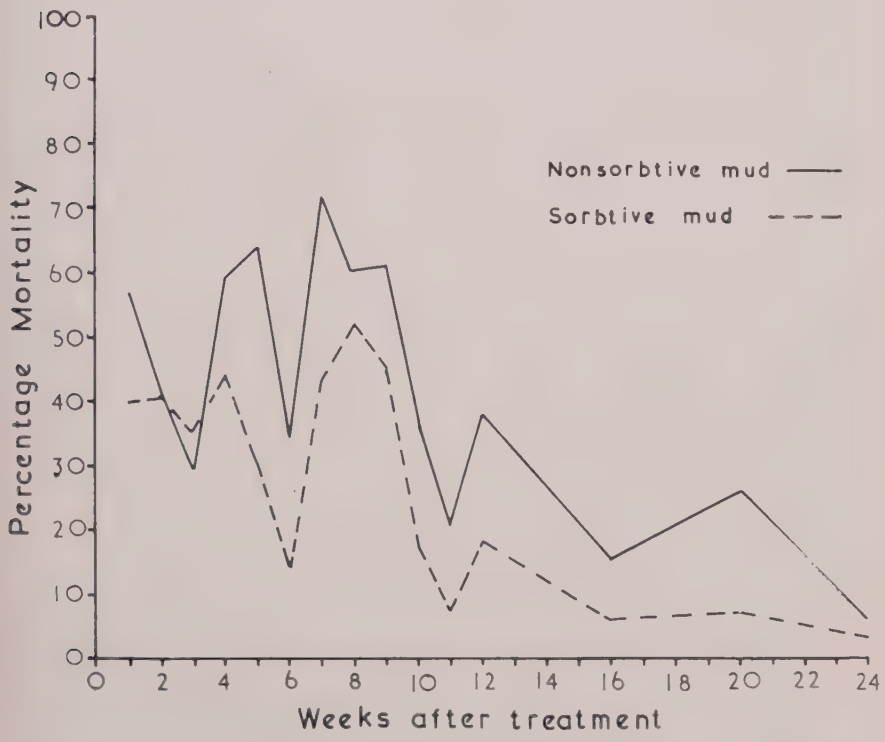


Fig. 3.—Percentage mortalities of adult female *A. gambiae* exposed for 30 minutes to dieldrin treated nonsorbtive and sorbtive muds.

with a maximum of 90.9 and a minimum of 58.1 percent. There was rain at weeks 2 and 3, 6–9 and weeks 17 and 18.

From the graph we see that there is a consistently higher kill by dieldrin on non-sorbtive mud than on sorbtive mud. This difference showed in all exposure tests but was not as apparent with the *A. aegypti* exposures on the dieldrin-treated surfaces nor with the exposures of the insects on the DDT-treated surfaces. The graph shows the general decrease in mortality over the twenty-four week period and the increase in mortality which occurs following an increased humidity (Burnett, 1956) although it is surprising that this effect was not shown to a greater extent on the sorbtive mud than on the non-sorbtive mud. The Njoro Nkubwa mud was found to be not completely non-sorbtive, and has been described by Burnett (1957) as less active than the active (sorbtive) mud which he used in the insecticide trials at Taveta, and this, together with the fact that the mud plaster on the walls was not as thick as it was intended, may explain why there was not a marked difference in mortalities recorded on the two surfaces, and why kills recorded on the sorbtive mud did not show the effect of changing humidity to a greater degree.

## CONCLUSIONS

1. The Relative Convenience of Handling the Two Types in the Field

The dish chamber was found to be convenient to use on a smooth surface and it was possible to set up a series of tests at closely timed intervals, but it could not be used if the surface was irregular. The conical exposure chamber could be used on all types of surfaces, and has been used successfully in the exposure of mosquitoes to treated thatch.

2. The Consistency of Results Obtained with Each Type of Exposure Chamber When Replicate Exposures Are Made

The main cause of the variations observed in this series of tests was the small numbers of insects per replicate; if about thirty insects had been placed in each chamber the variation would have been much smaller. The two chambers produced remarkably consistent results, which would be even more consistent if the chambers were large enough to contain 30 insects.

3. A Comparison of Results Obtained with the Two Types of Exposure Chamber When Applied to the Same Wall Surface

There is no difference in the results obtained with the two types of exposure chamber and it is considered that the results obtained with the two are fully interchangeable.

4. Which of the Two Types Indicate the Aging of Insecticide Deposits with the Greater Degree of Accuracy

As stated in section 3, there is no difference in the results obtained using the two types of exposure chamber, and they are equally good in showing the aging of insecticide deposits.

5. The Sorbtive Character of the Wall

The test technique is accurate enough to show the different mortalities produced when mosquitoes are exposed to dieldrin on non-sorbtive and sorbtive mud. The method also shows the effect of a changing humidity on the potency of the insecticide deposits and the general falling-off of the efficiency of the treated surface.

## ACKNOWLEDGMENTS

The authors are grateful to Dr. R. A. E. Galley and Mr. K. S. Hocking for permission to carry out this program of work, and to the World Health Organization for providing the wall exposure test kits. We also wish to thank the members of this Unit who assisted in the construction and chemical analysis of the test surfaces and for their many helpful comments.

Summary

With the aim to standardize all tests associated with assessing the efficiency of insecticide deposits, the World Health Organization provided two types of wall exposure chambers for a series of calibration tests. The chambers were both made of plastic, one basically a funnel and the other basically a petri dish.

The field trials revealed a major problem in carrying out bioassay tests; namely that the wall of the average native house is so broken and irregular that it is impossible to carry out these tests. The dish exposure chamber could only be used on a very smooth surface such as is found in experimental houses constructed for field trials, and for this type of experimental work it proved to be very good. The cone exposure chamber could be used on much rougher and more irregular surfaces, and has in fact been used by this Unit for bioassay tests on treated thatch. For general bioassay tests in the field the cone exposure chamber has many advantages over the dish exposure chamber.

Each chamber was shown to produce equally reliable and reproduceable results. The main factor responsible for the variation between replicates was the small number of insects in each chamber, and it is considered that 25–30 insects per replicate would result in a much closer agreement between replicates. There was no difference in the results obtained with the cone and the dish exposure chambers and in a series of tests to show the loss in efficiency of insecticide deposits the cone and dish results were combined. It was also shown that bioassay tests will give a picture of the general loss of the insecticide and also the effect of variations in humidity on insecticidal deposits on sorbtive and non-sorbtive surfaces.

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# A SURVEY OF POTENTIAL OVERWINTERING SITES OF *CULEX TARSALIS* COQUILLETT IN MINNESOTA[1]

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INTRODUCTION. The association of *Culex tarsalis* Coquillett with the transmission of the western equine encephalitis (WEE) virus in nature has led to speculation that this virus in its more northern ranges might survive the severe winters in infected hibernating female *C. tarsalis*. Unfortunately, to date there is little literature dealing with the specific sites in which *C. tarsalis* is capable of overwintering. A recent article by Rush *et al.* (1958) nicely summarizes the previous findings; since this article should be consulted in the original by those not familiar with the subject, its content will not be dealt with in detail here. It will suffice to note that: (1) food storage cellars in western Nebraska have harbored a few *C. tarsalis* until late in April; (2) information gathered from abandoned mines in Colorado and northern Utah did not indicate that these sites were especially favorable for overwinter survival of this species; and (3) several studies in California are not entirely applicable to the more rigorous climate of the north central United States. Rush and co-workers established rock piles as good hibernation sites in Washington, but they admit that this does not answer the question for the large plains areas where such habitats are not in abundance. In a study carried out in Colorado on the relation of soil temperature inversion to *C. tarsalis* emergence from hibernation, Bennington *et al.* (1958a) reported the recovery of a few *C. tarsalis* that had successfully overwintered in wild animal burrows and in artificially constructed shafts in the ground.

Aside from the suggestions given by the above findings, the question as to specifically where *C. tarsalis* hibernates in an area such as the northern plains states is unanswered. This study of potential overwintering sites of the mosquito in Minnesota has therefore been pursued the past three winters and it represents but one aspect in a much broader investigation on the bionomics of *C. tarsalis*. In spite of the gathering evidence that this species of mosquito does not take a blood meal before entering hibernation and hence would not harbor the WEE virus over the winter months (Bennington *et al.*, 1958b) and in spite of the inability of the present authors to observe any habitats containing successfully overwintering *C. tarsalis*, the information reported here offers data on the overwintering of mosquitoes in a geographical area for which very little is known. Furthermore, these findings tend, at least for the Minnesota region, to disagree with a statement, in a review by Jenkins (1950), that female *C. tarsalis* overwinter in protected places such as buildings, caves, and cellars.

The only previous reports of collections of hibernating mosquitoes in Minnesota are those of Owen (1937) relating the recovery of *Anopheles punctipennis* and *C. pipiens* in mid and late winter from artificial sandstone caves in the St. Paul area and of Wallace (1943) relating the capture and colonization of *C. pipiens* from a similar habitat. Owen also found *A. earlei* and *A. quadrimaculatus* in caves in the late fall, but none survived the very severe winter that followed.

METHODS. Beginning in October, 1957, excursions were made to various representative areas in and adjacent to Minnesota, with care being taken to choose regions most likely to have a sufficient population of *C. tarsalis* to give the best chance of discovery of hibernating female

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mosquitoes. A total of 27 artificial and natural caves as well as 35 other types of shelters consisting of empty outbuildings, chicken houses, rock piles, mushroom houses, log piles, vacant houses, potato houses, pig houses, and root cellars was inspected for their mosquito content. These 35 miscellaneous structures were at or near St. Paul, St. Peter, or Moorhead, Minnesota. Observations were made in all of these potential habitats at some time between the first of October and the middle of April.

Caves 1–6 (see Table 1) were all small artificial sandstone caves located in the Minnesota River valley near St. Peter, Minn. It might be noted at this point that the authors have arbitrarily classified as small caves those whose depth does not exceed 50 feet and whose volume is not greater than 2,500 cubic feet, as medium caves those whose depth lies between 50 and 250 feet with volumes not exceeding 25,000 cubic feet, as large caves those whose depths are variable but whose volumes are 25,000 to 100,000 cubic feet, and as very large caves those which contain at least a mile or more of tunnels and have a volume in excess of 100,000 cubic feet.

Caves 7–11 were situated along the St. Croix River in the Stillwater area; all were artificial sandstone caves, the first four being of medium size and the fifth being a very large, many-chambered commercial cave. Caves 12–18 were artificial sandstone caves, several of them in commercial use, in the St. Paul area. Caves 13 and 15 were small; cave 16 medium; caves 12 and 14 large. No estimates were made of 17 and 18. Cave 19, near Harmony, Minn., was a very large, well-maintained commercial natural limestone cave with several miles of passageways. Caves 20 and 21 were also natural limestone caves in the southeastern part of Minnesota; the former was only a large cavity in the hill adjacent to the much larger cave 21. The latter has an explored depth of well over two miles and is known as Mystery Cave. The remaining six were artificial sandstone caves. That at Ninninger, Minn., number 22, was medium-sized. Caves 23 and 24 were at Diamond Bluff, Wisconsin. The former was a large cave excavated for storage and supplied with artificial heat and the latter an unheated medium-sized cave higher up the same hill. Caves 25–27 were all very large and complex caves used as "sand mines." They invariably had several miles of spacious passageways.

The number of field workers varied from one to five and the time devoted to collecting or counting mosquitoes ranged from a few minutes to an hour (occasionally an hour and a half or longer). Since the emphasis was on numbers of species and individuals present at each visit, sufficient time was spent at each habitat to insure that most of the visible mosquitoes were counted and all or a portion of them were collected. The effort applied can understandably be correlated with the size of the cave and the numbers of mosquitoes present. To claim that all mosquitoes were accounted for would be hazardous, but it is believed that probably very few, if any, *C. tarsalis* were overlooked in the course of this survey. Searching was done by flashlight; all collected specimens were gently aspirated and placed in specially prepared ice cream cartons for transport alive to the laboratory where specific identification was made. Certain of the habitats were re-visited at intervals after the first inspection, both during the same winter as well as in the succeeding one or two winters.

In order to obtain information relative to the environmental conditions which prevailed in the various habitats, the temperature and often the relative humidity were recorded at the time of each visit. Also, a recording thermometer was placed in cave 2 at St. Peter and this provided a continuous reading of temperature over a period of 18 months.

Results. In an effort to find hibernating *C. tarsalis*, 103 visits were made to 27 different caves. A summary of the findings from each cave is given in Table 1. The dimensions stated for each cave are for length, width, and height, respectively. The date denotes the specific winter and

TABLE 1.—Mosquito species observed in caves of the Minnesota region during fall and winter

| Cave | Size (in feet) | Winter and inspections | *Culex tarsalis* | *Culex pipiens* | *Anopheles* species | Other | Total |
|---|---|---|---|---|---|---|---|
| 1 | 18 x 13 x 5 | 1957–58 (4) | – | 7 | 26 | – | 33 |
| | | 1958–59 (3) | – | 19 | 11 | – | 30 |
| | | 1959–60 (1) | – | 15 | 33 | 1[a] | 49 |
| 2 | 21 x 12 x 7 | 1957–58 (4) | – | 9 | 36 | – | 45 |
| | | 1958–59 (3) | – | 241 | 48 | – | 289[b] |
| | | 1959–60 (1) | – | 75 | 12 | 1[c] | 88 |
| 3 | 27 x 11 x 8 | 1957–58 (4) | 7 | 26 | 79 | – | 112 |
| | | 1958–59 (3) | 1 | 168 | 18 | – | 187 |
| | | 1959–60 (1) | 4 | 368 | 57 | – | 429 |
| 4 | 15 x 6 x 8 | 1957–58 (4) | 1 | 7 | 36 | – | 44 |
| | | 1958–59 (3) | 3 | 55 | 89 | – | 147 |
| | | 1959–60 (1) | 1 | 199 | 60 | – | 260 |
| 5 | 22 x 10 x 6 | 1957–58 (4) | – | 25 | 25 | – | 50 |
| | | 1958–59 (3) | 1 | 7 | 20 | – | 28 |
| | | 1959–60 (1) | 2 | 170 | 134[d] | – | 306 |
| 6 | 34 x 12 x 12 | 1957–58 (4) | 1 | 5 | 20 | 1[a] | 27 |
| | | 1958–59 (3) | 1 | 238 | 105 | – | 344 |
| | | 1959–60 (1) | 2 | 161 | 110 | – | 273 |
| 7 | 50 x 14 x 12 | 1957–58 (5) | – | 209 | – | – | 209 |
| | | 1958–59 (1) | – | 56 | – | – | 56 |
| | | 1959–60 (1) | – | 9 | – | – | 9 |
| 8 | 50 x 16 x 15 | 1957–58 (6) | – | 710 | 4 | 1[a] | 715 |
| | | 1958–59 (2) | – | 77 | 1 | – | 78 |
| | | 1959–60 (1) | – | 130 | 1 | – | 131[b] |
| 9 | 104 x 14 x 12 | 1957–58 (5) | – | 978 | 18 | – | 996 |
| | | 1958–59 (2) | – | 58 | 2 | – | 60 |
| 10 | 234 x 8 x 10 | 1957–58 (7) | – | 1707 | 4 | – | 1711 |
| | | 1958–59 (1) | – | 320 | – | – | 320 |
| 11 | Very large | 1957–58 (1) | – | 13 | – | – | 13 |
| 12 | 90 x 40 x 15 | 1957–58 (2) | – | 201 | – | – | 201 |
| 13 | 15 x 3 x 6 | 1957–58 (2) | – | 103 | 1 | – | 104 |
| 14 | Large | 1957–58 (2) | – | – | – | – | 0 |
| 15 | 12 x 12 x 8 | 1957–58 (2) | – | 55 | – | – | 55 |
| 16 | 110 x 14 x 12 | 1957–58 (2) | – | 164 | – | – | 164 |
| 17 | No estimate | 1957–58 (1) | – | 1 | – | – | 1 |
| 18 | No estimate | 1957–58 (1) | – | – | – | – | 0 |
| 19 | Very large | 1957–58 (1) | – | – | – | – | 0 |
| 20 | 80 x 30 x 20 | 1957–58 (1) | – | 4 | 1 | – | 5 |
| 21 | Very large | 1957–58 (1) | – | – | 9 | – | 9 |
| 22 | 100 x 14 x 8 | 1957–58 (1) | – | 51 | – | – | 51 |
| 23 | 1500 x 10 x 8 | 1957–58 (2) | – | 8 | 30 | – | 38 |
| 24 | 250 x 8 x 9 | 1957–58 (2) | – | 79 | 8 | – | 87 |
| 25 | Very large | 1957–58 (1) | – | – | – | – | 0 |
| 26 | Very large | 1957–58 (1) | – | 18 | 29 | – | 47 |
| 27 | Very large | 1957–58 (1) | – | 2 | – | – | 2 |
| Total | | 103 | 24 | 6748 | 1027 | 4 | 7803 |

[a] *Culex territans*.
[b] An additional 400–600 mosquitoes estimated here—none *C. tarsalis*.
[c] *Uranotaenia sapphirina*.
[d] Includes one *A. quadrimaculatus*.

the number in parentheses the visits to the cave during that period; the figure given for each mosquito count represents the largest population of a species known to have been present that season. It is recognized that at times it is difficult to distinguish with certainty between *C. pipiens* and *C. restuans*. Of the 6,748 specimens stated to be *C. pipiens* in Table 1, approximately half were confirmed microscopically in the laboratory as being this species. On the strength of this, the black-legged *pipiens*-like mosquitoes which were left in the caves have been regarded as *C. pipiens* in the accompanying tabulation. Although three species of *Anopheles* were found, only one of the 1,027 specimens was *A. quadrimaculatus*. The remainder consisted of *A. punctipennis* and *A. earlei,* the former consistently outnumbering the latter by a ratio of at least 10:1. In the interest of simplicity, no distinction between these two species has been made in the table.

In the three years of this study, almost 8,000 mosquitoes were observed in caves. Of this number, only 24 were *C. tarsalis*. Furthermore, this species was found solely in four caves situated near St. Peter and the latest date of occurrence for each year was Nov. 14, 1957, Nov. 28, 1958, and Oct. 29, 1959. In these and in a number of other caves successfully overwintering populations of *C. pipiens, A. earlei,* and *A. punctipennis* were present through the period of January to April.

Temperature data derived from the thermograph in cave 2 showed that the temperature reached its lowest point (34–36° F.) during the January and February period and then gradually rose to its highest point (59–63° F.) during the July to September period. Additional observations made in other caves substantiated the fact that temperatures in caves in which *C. pipiens* and *Anopheles* species overwintered never dropped below freezing, but at midwinter generally remained between 34° and 42° F. Several caves, such as numbers 15 and 16 in St. Paul, were open and exposed; in these, even though the initial *C. pipiens* population in late October numbered 55 and 164, respectively, none was alive in January when temperatures within had fallen to 22–25° F.

The walls of most caves are quite wet, often having water droplets on them and at times actively dripping water. Pools of water on the floors are not uncommon. The relative humidity appears to be near the saturation point. However, in this study, measurements using a sling psychrometer, a dew-point apparatus, and/or an electric hygrometer indicated relative humidities lower than expected. These readings ranged from 45–92 percent during the November through March period, with an unexpectedly high number of readings in the lower half of this range.

Only 4 of the 35 miscellaneous structures examined for mosquitoes yielded any specimens. These were as follows: (1) 123 *C. pipiens* from a mushroom house in St. Paul on Oct. 24, 1957; this building, however, is pasteurized every three months and would not be suitable for overwinter survival; (2) 100 *C. pipiens* from the basement of an occupied house in Minneapolis, Jan. 23, 1958; (3) 4 *A. punctipennis* from an abandoned log house at Bay City, Wisc., Jan. 28, 1958, and (4) 1 *A. punctipennis* in an outcrop on the side of a hill near Diamond Bluff, Wisc., on Oct. 26, 1957.

Discussion. While it is apparent from the three-year study just completed that many Minnesota caves are suited to the overwintering of mosquitoes, especially *C. pipiens, A. punctipennis,* and *A. earlei,* it is equally obvious that *C. tarsalis* did not select such sites for hibernation. Only 24 of 7,803 mosquitoes encountered in caves were *C. tarsalis* and all of these were limited to a series of small sandstone caves near St. Peter. Furthermore, no specimens of *C. tarsalis* were found in these caves later than November 28. This would seem to indicate that, although a small number of this species may enter caves in this area each fall, these habitats do not offer them a successful overwintering site. However, it should be pointed out that these same caves are suitable hibernation

sites for other species. Appreciable numbers of *C. pipiens,* an important vector of the St. Louis encephalitis virus, along with lesser numbers of *A. punctipennis* and *A. earlei* were observed to be alive on dates from the middle of January to the middle of April. This substantiates the observations of other workers who have found that the overwintering requirements of *C. pipiens* and certain *Anopheles* species seem to differ from those of *C. tarsalis.* When one considers the relative paucity of caves in southern and western areas of the state where *C. tarsalis* reaches its highest populations, this result is not too surprising.

From an inspection of Table 1, it is apparent that there was a disproportionately low number of *C. tarsalis* in comparison with the other species. This is especially evident when one considers the relative abundance of these species in summer light trap collections. In the St. Paul-Stillwater area, *C. tarsalis* is exceeded only by *Aedes vexans* in number while *C. pipiens* and *Anopheles* species are distinctly lower in rank. All other things being equal, if caves were the favored hibernation site of *C. tarsalis,* one might expect to find large numbers of this species in such situations. Since no *C. tarsalis* were found in caves except in the St. Peter area and since they occurred there only in limited numbers and only up to late November, one may conclude that, in Minnesota, caves are not hibernation sites for this species.

Keener (1952) reported the overwinter survival of some *C. tarsalis* in fruit cellars in western Nebraska and Dow *et al.* (1956) referred to unpublished observations made by Smith in similar habitats in Montana. Support for this type of habitat as being important in Minnesota is lacking, since an examination of structures such as root cellars, outbuildings, chicken houses, and potato houses failed to reveal any *C. tarsalis.* In Washington, rock piles have been established as potential overwintering sites (Rush *et al.,* 1958). This has not been confirmed in Minnesota, due to negative findings in the few rock piles investigated to date and to the scarcity of such a habitat type.

The possibility still exists that *C. tarsalis* can hibernate in such relatively inaccessible sites as rodent burrows. The results of Bennington *et al.* (1958a) in Colorado tend to support this possibility. Unfortunately, at the present time insufficient evidence is available for the Minnesota area. If indeed the female of this species does hibernate in Minnesota, it can be said rather definitely that some naturally occurring habitat, as yet uninvestigated, must offer the optimum conditions necessary for overwintering. In this study, caves and a variety of man-made structures have so consistently given negative results for *C. tarsalis,* and at the same time positive findings for other mosquito species, that it is the opinion of the authors that in Minnesota such habitats only rarely afford overwintering protection for *C. tarsalis.*

SUMMARY. In a three-year survey of potential overwintering sites of *C. tarsalis* in the Minnesota area, 103 visits to 27 different caves during the fall and winter months yielded a total of 7,803 mosquitoes. These consisted of 24 *C. tarsalis,* 6,748 *C. pipiens,* 3 *C. territans,* 1,026 *A. punctipennis* and *A. earlei,* 1 *A. quadrimaculatus,* and 1 *U. sapphirina.* All of the *C. tarsalis* were confined to a series of four sandstone caves in the St. Peter area and none was found later than November 28. Investigation of 35 structures other than caves resulted in the capture of only 223 *C. pipiens* and 5 *A. punctipennis.* The consistent inability to find any *C. tarsalis* in caves after November 28, coupled with the successful hibernation in these habitats of *C. pipiens,* an important vector of St. Louis encephalitis virus, and at least two other species, has led the authors to conclude that caves and man-made structures only rarely afford hibernation sites for *C. tarsalis* in the Minnesota region.

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# DDT RESISTANCE IN *ANOPHELES QUADRIMACULATUS* FROM THE U. S. ARMY CHEMICAL CENTER, MARYLAND *

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DDT-tolerance has been reported in *Anopheles quadrimaculatus* Say larvae by Kruse *et al.* (1952), Love and Kartman (1953), Gartrell and Ludvik (1954), and Hawkins (1956). Adult resistance to dieldrin, BHC and chlordane was reported by Mathis (1956). Martinez (1959) found *Anopheles quadrimaculatus* resistant to both dieldrin and DDT in areas that were intensively treated with insecticide for the control of cotton insects.

Results of tests conducted in 1958 and in 1959 indicate that a strain of *Anopheles quadrimaculatus* at Army Chemical Center, Maryland, is DDT-resistant. Test results were compared with those obtained with a DDT-susceptible strain from the United States Department of Agriculture's laboratory at Orlando, Florida.

The Army Chemical Center anopheline population was subjected to intensive treatments from 1946 to 1958 with aerial and ground applications of DDT for the control of mosquitoes and other insects of medical importance. During 1959 the Army Chemical Center was treated five times with aerial sprays of malathion at 0.5 lb. per acre and received numerous ground treatments with DDT and malathion. The area adjacent to the Center is mostly agricultural land and is frequently treated with both chlorinated-hydrocarbon and phosphorus-containing insecticides for the control of insect pests of the various crops, possibly further exposing the anopheline population to insecticides. The Orlando *Anopheles* have been reared under laboratory conditions for seventeen years at Orlando and have not been treated with insecticides.

Methods and Materials. Adult females of the Army Chemical Center (ACC) strain of unknown age were collected with aspirators from a donkey barn located in

* This material has been reviewed by the Office of The Surgeon General, Department of the Army, and there is no objection to its presentation and/or publication. This review does not imply any indorsement of the opinions advanced or any recommendation of such products as may be named.

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a woods adjacent to the main part of the cantonment area. Most of the females were recently engorged and either used for testing on the day of collection or confined in cages for oviposition or testing at a later date. Adult females of the Orlando strain were maintained in the laboratory at 83° F. and 60 percent relative humidity and were tested at 3 to 5 days of age after engorgement. Larvae of both strains were reared without temperature control, in temperatures which varied from 80° to 97° F., and were tested in the late third or early fourth instar. They were fed a powdered mixture of 60 percent whole wheat flour, 25 percent powdered yeast, 10 percent dried beef blood and 5 percent dried skimmed milk. World Health Organization test kits were used for all tests except for one series against larvae. The larvae were subjected to 250 ml. of an alcohol-water suspension of the insecticides, and the adults were exposed to filter papers impregnated with Risella oil solutions of the insecticide. During the 24-hour test periods, 80° F. ± .5° F. temperature and 75 percent ± 2 percent relative humidity were maintained in a constant temperature and humidity cabinet (Aminco Aire). Adult mortality was recorded 24 hours after the exposure period except in tests where exposures were continuous for more than 24 hours. Larval mortality was recorded 24 hours after continual exposure to insecticide suspensions. Mortality in the controls throughout the tests ranged between zero and 10 percent and in most of the tests was 5 percent or less.

DISCUSSION. Against the larvae of the ACC strain, DDT at 2.5 parts per million failed to cause kills greater than 90 percent in any test. Against larvae of the Orlando strain, DDT at 0.004 parts per million caused 87 to 94 percent kills, agreeing favorably with results of previous tests reported by Deonier *et al.* (1946), and by Keller *et al.* (1951), who reported an LC50 of 0.0021 p.p.m. These results demonstrate that the larvae of the ACC strain are highly resistant (about 600-fold) to DDT. The results of these tests are summarized in Table 1.

Against the adult females of the ACC strain, exposures of 1 to 54 hours to 4 percent or 8 percent DDT residues failed to cause greater than 90 percent kill. Females of the Orlando strain exposed 1 hour to 2 percent DDT produced between 85 percent and 90 percent kills and similar exposure of the ACC strain produced 10 percent to 25 percent kills. The results of these tests which are shown in table 2 demonstrate that there is a very high degree of DDT resistance in the adults of the ACC strain.

In very limited tests female *Anopheles*

TABLE 1.—Susceptibilty of *Anopheles quadrimaculatus* larvae to DDT (Averages of duplicate tests of 20 or 25 late third or early fourth instar larvae each)

| Date of test | Percent kill at indicated concentration in p.p.m. | | | | | LC50 p.p.m. |
|---|---|---|---|---|---|---|
| | 0.004 | 0.02 | 0.1 | 0.5 | 2.5 | |
| | | | ACC strain | | | |
| 22 July 1959 | 0 | 15 | 40 | 90 | 90 | 0.11 |
| 22 July 1959 | 0 | 0 | 55 | 75 | 90 | 0.09[4] |
| 22 July 1959 | 0 | 5 | 40 | 55 | 70 | 0.30 |
| 31 Aug. 1959 | 5 | 10 | 15 | 75 | 87.5 | 0.25 |
| 2 Sept. 1959[1] | – | – | 4 | 88 | 78 | – |
| | | | Orlando strain | | | |
| 17 Sept. 1959 [2, 3] | 87 | 100 | 100 | 100 | 100 | <0.004 |
| | 94 | 94 | 100 | 100 | 100 | <0.004 |

[1] Progeny from survivors of field-collected females subjected to 4 percent DDT for 1 hour.
[2] Average of 4 tests of 25 larvae each.
[3] Laboratory-prepared ethanol solution.
[4] Determined by extrapolation.

TABLE 2.—Susceptibility of *A. quadrimaculatus* females to residues of DDT (20 females per test) except as otherwise noted

| Date of test | Exposure period (hrs.) | Percent kill at indicated percent concentration | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0.25 | 0.5 | 1.0 | 2.0 | 4.0 | 8.0 | LC50 |
| **ACC strain** | | | | | | | | |
| 8 Sept. 1958 [1, 2] | 1 | 0 | – | – | – | – | 0 | – |
| 8 Sept. 1958 [1, 2] | 2 | 20 | – | – | – | – | 20 | – |
| 9 Sept. 1958 [1] | 54 | – | – | – | – | 50 | 50 | – |
| 10 Sept. 1958 [1, 2] | 30 | – | – | – | – | – | 60 | – |
| 10 Sept. 1958 [1, 2] | 24 | – | – | – | – | – | 60 | – |
| 15 Sept. 1958 [2] | 42 | 50 | 70 | 60 | 80 | 90 | 80 | – |
| 18 Sept. 1958 [1] | 30 | – | 30 | 30 | 30 | 40 | 62 | >4.0 |
| 22 Sept. 1958 [1] | 30 | – | – | 45 | 35 | 50 | – | 4.0 |
| 22 Sept. 1958 [1] | 30 | – | – | 45 | 35 | 50 | 50 | – |
| 25 Sept. 1958 [1] | 30 | – | – | 45 | 45 | 70 | 70 | >2.0 |
| 25 Sept. 1958 [1] | 30 | – | – | 45 | 37 | 89 | 80 | – |
| 19 Dec. 1958 [1] | 30 | – | – | – | – | – | 45 | >8.0 |
| 9 June 1959 [2] | 1 | – | – | – | – | 10 | – | – |
| 13 July 1959 | 1 | 20 | 25 | 25 | 35 | 45 | – | >4.0 |
| 27 July 1959 | 1 | 0 | 5 | 10 | 25 | 25 | – | >4.0 |
| 3 Aug. 1959 | 1 | 0 | 15 | 15 | 15 | 55 | – | – |
| 17 Aug. 1959 | 1 | 5 | 0 | 5 | 10 | 30 | – | >4.0 |
| 20 Aug. 1959 | 16 | – | – | – | – | 80 | – | <4.0 |
| 27 Aug. 1959 | 1 | – | – | – | 10 | 30 | – | >4.0 |
| 1 Sept. 1959 [1] | 1 | – | – | 5 | 5 | 15 | – | >4.0 |
| **Orlando strain** | | | | | | | | |
| 25 Sept. 1959 | 1 | – | – | – | 90 | 100 | – | <2.0 |
| 28 Sept. 1959 | 1 | 0 | 10 | 40 | 85 | 95 | – | 2.2 |
| 29 Sept. 1959 | 1 | 5 | 15 | 55 | 90 | 95 | – | 0.9 |

[1] Part of this high resistance might be attributed to accumulation of internal fat required for successful hibernation.

[2] Ten insects per test.

*punctipennis* (Say) and *Anopheles crucians* (Wied.) collected among the *Anopheles quadrimaculatus* were all killed by dosages of DDT that killed less than half of the *A. quadrimaculatus* indicating that these two species are considerably more susceptible to DDT, although they were probably subjected to the same treatments.

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# OPERATIONAL AND SCIENTIFIC NOTES

## GYNANDROMORPHISM IN *Aedes taeniorhynchus* (WIEDEMANN) [1]

PATRICK T. M. LUM

Heretofore approximately 39 cases of gynandromorphism in mosquitoes have been reported. Since the summary by Kitzmiller (1953) in which 34 cases scattered in the literature were brought together, other gynandromorphs have been reported for *Culex pipiens* issp. *molestus* Forskål by Gratz (1954), Keh (1955), and Ghelelovitch (1957), *Culex salinarius* Coquillett by Davis (1957), and more recently *Mansonia uniformis* (Theobald) by Laurence (1959). Of the 34 cases reviewed by Kitzmiller (1953) 14 were in the genus *Aedes* representing five species: *Aedes aegypti* (Linnaeus), *Aedes punctor* (Kirby), *Aedes detritus* (Haliday), *Aedes pullatus* (Coquillett), and *Aedes canadensis* (Theobald).

The following note is on three gynandromorphs of *Aedes taeniorhynchus* (Wiedemann) all of which were from laboratory cultures. Two were reared from larvae collected in the field and the third reared from eggs deposited by a wild caught female. In the case of the latter the number of offspring from this female was 75. All were normal except for the sole gynandromorph.

The differentiation of all three gynandromorphs was bi-polar with the anterior end (head and thorax) characteristically female and the posterior end (abdomen) characteristically male. Specimens 1 and 2 were identical and 3 differed slightly in that the legs showed both male and female characters. The following description and figure (Fig. 1) are of specimen number 3.

Head, palpi, antennae, eyes, and proboscis as in normal female. Thorax with scaling and markings also as in normal female; tarsi intermediate: right front- and mid-tarsi with claws as in normal male, left front- and mid-tarsi as in normal female, both hind-tarsi as in normal male. Wings: right wing slightly larger than left wing with scalings on both as in normal female. The abdomen and terminalia entirely male, with the hypopygium fully rotated.

The external appearances of gynandromorphs 1 and 2 were similar to that described for 3 except that the tarsi were completely female.

The specimens were not noticed among the other males and females in the colony cage until five days after emergence. All had access to sugar solution and water which they took readily, but attempts to induce blood feeding failed for all three. Gynandromorph 3 did, however, make a feeble attempt at probing on the author's arm. Compared to the other mosquitoes housed in the same cage, the specimens exhibited little flying activity and were in general rather inactive.

FIG. 1.—Gynandromorph of *Aedes taeniorhynchus* (Wiedemann) exhibiting bi-polar differentiation. Left middle leg missing.

The finding of only three gynandromorphs among thousands of mosquitoes reared and studied in the laboratory further exemplifies the rarity of these abnormal forms, despite the difficulty of detecting one individual in a large colony. The absence of gynandromorphs in light trap collections at the laboratory raises the question that they may not be attracted to light and may well have unconventional behavior patterns.

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## A Fan Trap for Collecting Biting Insects Attacking Avian Hosts

W. E. Snow, Eugene Pickard, and R. E. Sparkman, Malaria Control Branch, Division of Health and Safety, Tennessee Valley Authority, Wilson Dam, Alabama.

Lumsden (1958) developed a fan-type trap to capture mosquitoes in the vicinity of small vertebrate baits. In preliminary trials, fans pulled a stream of air horizontally across the bait at regular intervals in such a way that the attacking insects would be carried into a screen sleeve provided with a killing jar. The fan was operated intermittently so that insects could approach the bait undisturbed during the periods when the fan was not running. Subsequent tests showed that a suction-type trap with the fan placed above the bait was more efficient.

In 1957–1958, TVA constructed a recirculating type of trap different from Lumsden's but using some of his principles. The TVA trap was designed for use in field studies to determine host-parasite relationships of biting Diptera frequenting bottomland forest canopy.

The drawing (Fig. 1) shows the assembled trap with the upper sliding panel removed. The frame of this trap is constructed of ¾″ × 2″ wood uprights and 16-gauge sheetmetal channels (2″ × ¼″ and ¾″ × ¼″) with welded corners. The blower (A) is a twin centrifugal type 2CO69 "Dayton" with two 4½″ diameter-balanced blower wheels in direct drive on each end of the motor shaft. Each of the blowers has a 3″ × 3″ discharge opening. These airstreams are brought together to form a common discharge having a diameter of approximately 10 inches. This opening allows the airstream to completely surround the bait (B). A sheetmetal cone 8″ in diameter with the cup side uppermost was centered in this air discharge duct to augment the velocity. This cone also serves as a collector for droppings from the small chicken used as bait. Sheetmetal collars (C) are used to convey the airstream to the height required. The bait was restrained in a metal basket (B) constructed of large mesh wire with a reversible hinged cover. The chicken's head protrudes through a small opening in the cover. The position of the bait in respect to the airstream and distance below the trap hood can be controlled by adjusting the four metal rods (D) running from the lower rim of the bait basket through holes in the wooden frame.

The air blast from below the bait is directed into the center of the sheetmetal hood (E) above the bait. When the airstream reaches the hood, it has lost most of its velocity due to friction with the bait and surrounding atmosphere, but the hood and the cross section of the throat area (F) leading to the suction intake duct were designed to produce a gradual increase in velocity which prevents the escape of insects caught in the airstream. The insects are separated from the airstream by means of a fine mesh (32) wire cone (G) and collected in a pint killing jar (alcohol) (H). The cone has a large surface area which minimizes the loss in velocity. Both the cone and killing jar are located in a reversed, tapered section of the intake duct. The screened cone and killing jar can be removed by sliding the cone out through this panel opening. While the trap is in operation the sliding panel and the spring-loaded door (I) are both kept closed. The killing jar alone can be attended by opening the lower door.

For ease of handling and transporting, the complete unit is constructed in two matching parts of about the same size. By removing four small bolts the upper section, consisting of lifting eye,

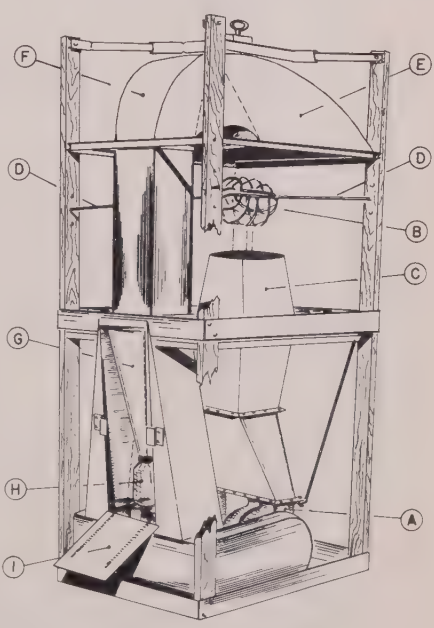


Fig. 1.—Assembled fan trap for collecting biting insects attacking avian hosts. See text p. 315 for explanation.

hood, upper section duct, and bait basket, may be removed as a unit. The upper section weighs 20 pounds and the lower section 36 pounds. The dimensions of the trap when assembled are 4.5 feet high by 2.0 feet wide.

An automatic control unit *, consisting of a recycling cam timer (Series CM-5) and B-15 gear and rack assembly, was used to activate and deactivate the blower. The timer has a five-minute periodicity that can be adjusted to provide 0 to 100 percent "on" or "off." The most suitable cycle of operation was two minutes "on" and three minutes "off." This unit and the portable gasoline generator used to furnish power for operation of fan were located approximately 150 feet from the base of the tree in which the fan trap was suspended.

The trap was operated during the summers of 1958–1959 in connection with a program to investigate the feeding habits of biting Diptera in natural and altered bottomland habitats at Beaverdam and Blackwell Swamps near Decatur, Alabama. The fan trap collections were made in hardwood forest canopy to supply information on Diptera attacking avian (chicken) bait. In order to obtain a wider scope of the insect biting population, collections from human bait at ground and different canopy levels were also made. These collections were made using another oak tree approximately 150 yards from the fan trap location. The results are given in Table 1.

TABLE 1.—Record of female mosquitoes and heleids taken at different locations and elevations by two sampling methods using human host and fan-type trap during the crepuscular period, Beaverdam Swamp, Greenbrier, Alabama, June 23, 1958

| Method: | Fan-type bait trap * | Aspirating on man ** |
|---|---|---|
| Collection period: | 1825–2035 | 1845–2015 |
| *Species* | | |
| *Anopheles quadrimaculatus* | 1 | 3 |
| *Mansonia perturbans* | 19 | 35 |
| *Culicoides baueri* | 26 | 5 |
| *C. guttipennis* | 5 | 9 |
| *C. hinmani* | 22 | 0 |
| *C. paraensis* | 0 | 2 |

* 35-foot level in forest canopy—avian bait.
** 75-foot level in forest canopy.


## SUMMARY

A new trap for collecting biting insects has been made. The unit is virtually a closed system with a twin centrifugal fan taking in air from the hood above the bait and passing it through the screen cone separator and discharging the blast of air beneath the bait where it is recirculated. Based on two summers' observations, it appears that this trap has sufficient airflow to capture small Diptera such as *Culicoides* and *Phlebotomus,* but an increase in velocity appears essential to sample mosquito populations adequately.



## ACKNOWLEDGMENTS

The authors wish to express their sincere appreciation to Dr. G. E. Smith, Chief Biologist, under whose supervision the investigation was carried out, and to Mr. G. S. Christopher, Chief, Malaria Control Branch, for useful comments relative to the construction and operation of the fan trap.


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* Industrial Timer Corporation.

## A MOSQUITO-TIGHT CAGE


MICHA BAR-ZEEV and RACHEL GALUN, Israel Institute for Biological Research, Ness-Ziona, Israel.


The escape of mosquitoes from breeding and maintenance cages is a great nuisance, especially where genetics and resistance studies are carried out, since escaped mosquitoes may re-enter experimental cages and thus render such experiments futile. In most mosquito cages described (Young & Burgess (1946), Boyd (1949), Barnett (1955), Trembley (1955), Hartzell *et al.* (1958)), a sleeve is used which makes possible all required manipulations inside the cage; this arrangement, however, does not prevent the escape of mosquitoes on those occasions when materials (eggs, food, animals, etc.) are transferred. The construction of a mosquito cage in which all the required manipulations could be carried out without ever opening the cage (except when no adults are present, e.g. for cleaning and introducing the pupae) is described.

The cage (40 x 44 x 40 cm.) (Fig. 1) has a wooden frame and bottom and a 20-mesh metal screen on all sides except the front which is only partly screened and divided into two parts: one part (40 x 15 x 15 cm.) is fixed, the other (40 x 30 x 33.5 cm.) removable by means of screws and snaps (Detail A). This removable part is lined around the inner edge with a strip of rubber sponge and around its outer edge with a metal frame to insure tight sealing.

Larvae reared in any suitable container are filtered after pupation from the rearing medium, put into a plastic dish (31.5 x 23.5 x 8.0 cm.) (Detail D) containing fresh water, and placed on the floor of the cage slightly inclined towards the front. A metal tube (1 cm. in diameter) con-

nects the lower part of the dish and protrudes outside the cage through a suitable opening. The tube can be opened and closed by means of a clipped rubber tube (Fig. 1 and Detail D). When all or most of the adults have emerged, the tube is opened to drain the water into a reservoir capable of preventing any escape of mosquitoes that may be drained with the water.

In order to provide food, a wad of cotton soaked with honey, or an inverted small jar filled with a 10 percent sugar solution and closed with cotton, is placed over the screen on the top of the cage. If a blood meal is to be offered to the mosquitoes, two rats, which have had the hair clipped from their backs, are introduced each into a conical cage (23.5 cm. long, 9 cm. high on the

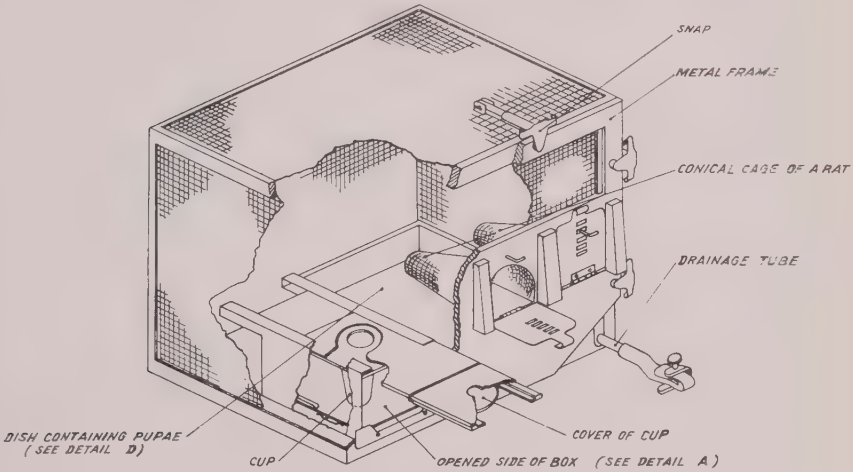
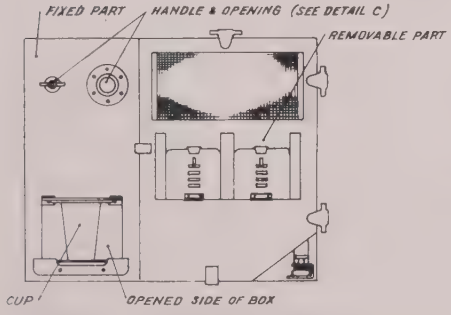
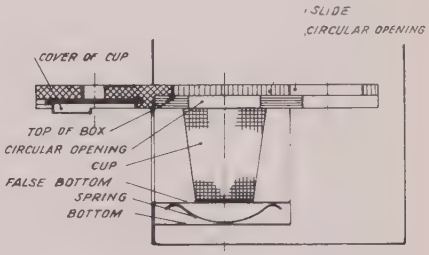


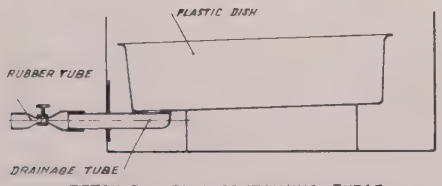

FIG. 1 MOSQUITO CAGE



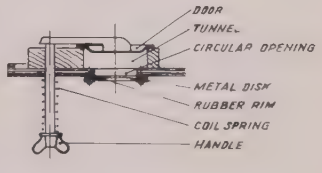

DETAIL A. FRONT VIEW OF THE CAGE




DETAIL B. BOX WITH CUP FOR EGG COLLECTION




DETAIL D. DISH CONTAINING PUPAE




DETAIL C. DEVICE TO OPEN AND CLOSE CIRCULAR OPENING (SEE TEXT)

front end, 3 cm. high on the rear end) through an opening (9 cm. high, 9 cm. wide) on the removable front part of the cage. Each of these conical cages (Fig. 1) consists of a 20-mesh metal screen, a metal platform and a movable metal tray which can be lifted upwards to force the back of the rat against the screen. A door, having slits close to each other along its longitudinal axis, closes the opening, one of the slits on the door being hinged into a pin situated just above the opening to hold the rat against the screen. This method of offering a blood meal is an adaptation of the method used in the laboratories of the C.D.C., Savannah, Ga., and has also recently been described by Pollard (1960).

If eggs are to be collected a cup (9.5 cm. high; 7.2 cm. upper diameter) containing water or, in the case of *Aedes* species, lined with filter paper, is introduced into a metal box (15.0 x 10.5 x 13 cm.) with a plastic top. The box, the front part of which is open, is situated on the lower left hand corner of the cage, below the fixed front part. This box (Detail B) has a false bottom on springs which can be lowered when the cup is introduced. The upper side of the box has a circular opening 7 cm. in diameter, into the rims of which the mouth of the cup is fitted, and tightened by means of the bottom springs. A slide (49 x 10.5 cm.), having a similar circular opening, can slide along the top of the box, thus closing and opening the mouth of the cup. Ordinarily, the slide is so placed that the mouth of the cup is open towards the cage to enable the mosquitoes to lay eggs. When eggs are to be taken out, the mouth of the cup is closed by moving the slide. The cup is then pulled out by sliding it along the box until it reaches a circular cover, 9 cm. in diameter, with a wide rim, 1 cm. high, on its front side, which was placed previously in an appropriate slit in a prolongation of the slide. The cup, thus covered, is removed and placed in a refrigerator for a few minutes in order to inactivate any mosquito which may have reached the cup. These mosquitoes are killed and removed. Another cup is then introduced into the box by the same method.

In order to remove mosquitoes from the cage for experimental purposes, a circular opening (4 cm. in diameter) with a rubber rim (0.5 cm. wide) is located on the upper fixed part of the front cage (Detail C). By pressing and turning the handle, which is fitted with a coil spring and connected to a circular inside door, the opening can be closed and opened. A cavity 2 cm. deep connects the door and the outer opening. An aspirator which fits the entrance of the opening, and which is made mobile by the rubber rim, is introduced into the cavity. The door is then opened, and the aspirator is pushed inside. After mosquitoes are sucked in, the aspirator is pulled back until its end is close to the rim of the opening. The door is then closed, and the aspirator can be removed.

The cage described here has been used successfully in our laboratory as a continuous source of eggs and mosquitoes of several species and strains, without fear of contamination.

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## TWO NEW RECORDS OF MOSQUITO SPECIES FOR MINNESOTA

F. E. COOK, Laboratory Technician, Metropolitan Mosquito Control District

During the 1959 season two additional species of mosquitoes were added to the list of 47 species already recorded in Minnesota (Barr, 1958). The two new records were *Psorophora (Janthinsoma) ferox* (Humboldt) and *Psorophora (Grabhamia) confinnis* (Lynch Arribálzaga).

Three collections of *Psorophora ferox* larvae were made: Anoka County, Blaine twp., Sec. 3, B.S.I., IX–1–59; Hennepin County, Bloomington (T116–R21), Sec. 21, B.S. 11, IX–4–59; Hennepin County, Bloomington (T27–R24), Sec. 23, B.S. 10, IX–3–59. The larvae were identified, and some were reared for more positive identification. Identified specimens are now in the University of Minnesota collections. Prior to this time, *P. ferox* has been erroneously reported from light trap specimens taken by Riley and Chalgren in 1938. On subsequent examination these specimens were determined to be *Psorophora horrida.*

Only one collection of *Psorophora confinnis* was made (Washington County, Woodbury twp., Sec. 4, B.S. 3, VIII–29–59). This was a fourth instar larva and is now in the University of Minnesota collections.

The occurrence of *Psorophora horrida* in this state was confirmed by three biting collections: Anoka County, Columbus twp., Carlos Avery Game Farm, VIII–18–59; Scott County, Sand Creek twp., Sec. 19, park, VI–18–59; Scott County, Glendale twp., Sec. 31, B.S. 3, VI–19–59.

In addition to these records for *Psorophora,* the

first larval collections of *Culex (Melanoconion) erraticus* were made in Hennepin County (Hennepin County, Golden Valley (T29–R24), Sec. 18, B.S. 9, IX–11–59: IX–9–59). Adult specimens of this species were taken in light traps at Wabasha in 1939 by Peters and Daggy and again in 1941 by Peters. These are the only previous records for the state.

This is a large mosquito control district (approx. 2850 sq. mi.) embracing six counties and, thereby, providing a very wide range and variety of habitats. As a result, from our combined larval, light trap, and biting collections we have, to date, obtained 38 of the 49 species known for this state.

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## TWO ADDITIONAL CHARACTERS IDENTIFYING *Culex tarsalis* COQ.

B. CHANIOTIS and W. ILTIS, Department of Entomology, University of California, Davis.

Within the genus *Culex* there is frequently confusion in separating the two closely related species *C. tarsalis* Coq. and *C. peus* (Speiser), especially when the specimens for identification are worn, mutilated, or covered with moth scales and dirt, as is usually the case when they are caught in light traps.

For differentiating these two species almost all systematic books and manuals utilize two conventional characters which are undoubtedly reliable. They are: (1) presence of white scales in a narrow line or in a row of spots on the outer surface of femora and tibiae (*C. peus* lacks these), and (2) presence of a dark inverted V on the venter of most abdominal segments (*C. peus* has rounded spots instead).

These characters have proved sufficient if the specimens for identification are in good condition, but in the case of mosquitoes obtained from light traps the separation sometimes is difficult and the decision must rest on guesswork, or in regard to males on examination of the genitalia, a time-consuming process.

The authors have utilized two additional characters which serve to differentiate the species in doubtful cases. These are: (1) white scales on the base of the costal vein of the wing, and (2) two prominent tufts of white scales on the inner margins of the antennal tori. Both of these characters are present in *C. tarsalis* whereas they are lacking in *C. peus;* however the bushy development of the antennae in the males makes the antennal character inconspicuous.

Hundreds of specimens of both species from various parts of the state of California have been checked, and without exception have been found to conform with our findings. It should be said that these additional characters are not newly discovered. They are mentioned in the description of *C. tarsalis* (Howard, Dyar and Knab, 1915, v. 3, p. 232) but they have never been stressed for practical purposes.

## A RECORD OF *Anopheles filipinae* IN NEPAL

SHREEDHAR PRASAD PRADHAN [1] and HAROLD W. BRYDON [2]

During 1959 the Nepal Malaria Eradication Organization sent survey teams into different parts of Nepal to collect pre-eradication epidemiological data. On December 17 in the village of Dharampani Kaymen in a remote hilly region of District West Number 3 (Fig. 1), S. P. Pradhan found that he had collected one adult female specimen of *Anopheles filipinae* in an early morning collection.

Dr. D. K. Viswanathan and Dr. D. R. Mehta of the World Health Organization, New Delhi, India further confirmed the identification of the species.

As far as can be determined, *A. filipinae* has not been previously reported from either Nepal or from India, which is closely related both geographically and climatologically to Nepal.

Manalang (1930) reported that adult *A. filipinae* had been collected and described from Bulucan, Philippine Islands. He further stated that the larval form of the species was found in impounded spring water, shaded or unshaded, clear or muddy streams, rivers, flowing irrigation ditches, pools and lakes in the locality of Ungkong Managa near Bulutong stream (Boyd, 1949). The larvae are also occasionally found in association with aquatic vegetation such as *Pistia, Ipomoea,* and water hyacinths. Very little is known about the habitats of adult *A. filipinae* (Foote, *et al.,* 1959). However, D. E. Eyles (1944) has reported that experimental flight range tests have been performed upon the species and that specimens have been observed to travel as far as 3,300 feet from the point of release.

The village of Dharampani Kaymen, from which the species was collected in Nepal, lies at

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[1] Entomologist, Nepal Malaria Eradication Organization.

[2] Entomologist Advisor, International Cooperation Administration.

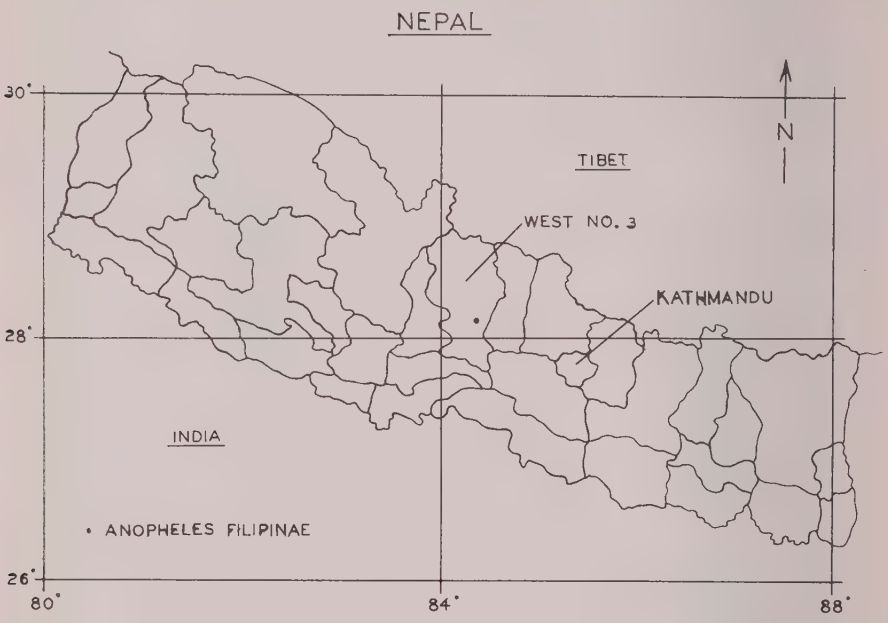


FIG. 1.—Map of Nepal showing District boundaries and the location of the *Anopheles filipinae* collection in District West No. 3 and its relation to the nation's capital, Kathmandu.

an elevation between 1,600 to 1,800 feet above sea level. The village is situated on the base of a hill near a small sparse forest and a clear spring-fed stream flows through the forest and next to the village. About one-half mile away the huge Seti Gandaki river runs toward the south. The adult specimen was collected from a building in which both humans and ruminants live.

*A. filipinae* is not common throughout the Philippine Islands; however, it may act as a vector in the Philippines where malaria occurs abundantly and wherever the population of the species is high. The species has been found naturally infected, but with a very low sporozoite rate. No known attempt has been made to infect the species experimentally under laboratory conditions (Foote, *et al.*, 1959).

*Anopheles minimus* is presently the main vector of malaria in Nepal and W. V. King (1932) states that *A. filipinae* falls in the so-called *funestus-minimus* subgroup of *Anopheles* and that it was originally known as a variety of *A. minimus*.

The literature indicates that the ecological conditions in the Philippine Islands from which *A. filipinae* was collected are apparently similar to those from which the species was collected in Nepal.

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## NOTE ON EFFECTS OF DROUGHT ON LARVAE OF *Aedes vexans* MEIGEN (DIPTERA: CULICIDAE)

H. G. JAMES, Entomology Research Institute for Biological Control, Research Branch Canada Department of Agriculture, Belleville, Ontario.

Gibson (1933) and Twinn and Hay (1935) indicated that in Ontario the floodwater mosquito *Aedes vexans* Meigen occurs only in comparatively small numbers in dry summers. When

there is heavy and continuous precipitation, however, larvae become very abundant and, unless controlled, an outbreak ensues (Henkel, 1936).

Heavy, though isolated precipitation sometimes results in populations of larvae that are later killed by rapid evaporation of the surface water. The fate of such larvae was investigated in the laboratory by Bick and Penn (1947), who found that third- and fourth-instar larvae of *A. vexans* survived continuous drought for 120 and 96 hours respectively.

In 1959 heavy rainfalls occurred at Stirling, Ontario, on July 6 (.54 in.) and July 9 (.49 in.) (Canada Dept. of Transport, Meteorological Branch). These resulted in high larval populations of *Aedes vexans* four miles to the south at Chatterton (Marsh Hill), in a wooded swamp that had been dry underfoot since mid-June. First-instar larvae were particularly abundant on July 7, in a former semi-permanent pool as well as in several of the deeper temporary pools.

On July 14, eight days after the first flooding, however, no surface water remained in any of the pools and the larvae were unable to develop beyond the third stage. When soil samples from the semi-permanent pool were taken to the laboratory and reflooded large numbers of dead larvae of *A. vexans* were found, some of them mutilated, probably by staphylinid beetles that were numerous in the samples.

To determine whether any unhatched eggs still remained, four soil samples, each a quarter of a square metre in area, were taken from the semi-permanent pool and similar samples were taken from the margins of a temporary pool. The samples were dried further in the laboratory for eight days and then reflooded. No additional larvae were obtained from the semi-permanent pool samples, but a few larvae hatched from those of the temporary pool, possibly from soil that had not been inundated previously. This would indicate that all larvae that hatched in the flooded section in both types of pool perished. Thus, the lack of additional rain from July 9 to July 18 prevented a local outbreak of this well-known migrating mosquito.

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**Disneyland is a unique place, and the AMCA-CMCA meeting will have unique features:**

**Tuesday,** January 31—keynote address by Dr. Malcolm H. Merrill, Director, California State Department of Public Health. Dr. Louis L. Williams of the Pan American Sanitary Bureau will then summarize our country's interest and participation in mosquito control activities throughout the world. **Wednesday,** an equipment demonstration will be held at 11:00 a.m. followed by a special luncheon to recognize the men and organizations who furnish the tools and larvicides for our mosquito control program. That afternoon the relationship of mosquito control to the public well-being will be presented by a symposium. **Thursday,** specific research papers on biological control, Chironomidae, log ponds, insecticides and insecticide problems, followed by a symposium summarizing the many research efforts throughout the world. The afternoon of the last day has been reserved for a symposium on recent developments in arthropod borne viruses in North America. Plus concurrent sessions for the submitted papers.

*(Please turn to page 326)*

# NEWS AND NOTES

AUSTIN W. MORRILL, JR.

Abler entomologists than we, with better right to memorialize him, are preparing eulogies for Stan Freeborn, but we beg leave to say our small word too. From the moment when he loped breezily into our first session of Entomology I, Stan epitomized for us the energy and enthusiasm of youth and symbolized everything we wanted to be as an entomologist. He never ceased to do so, to the moment we last spoke to him a few short weeks ago. His informal, natural friendliness made contemporaries of his juniors and intellectual equals of those of us who could never hope to earn such equality. He elevated Entomology as a science, just as knowing him elevated us as entomologists. Wherever he is, in that "bourn from which no traveller returns," we envy those who will henceforth be privileged to know him and to have him with them.

WE HAVE BEEN ENJOYING OUR ANNUAL MILITARY TRAINING DUTY IN WASHINGTON, D. C. AND WHILE WE WERE THERE WE PERUSED THE LISTS OF ENTOMOLOGISTS WHO ARE ACTIVE IN THE ARMY RESERVE and we were also interested in checking over the lists of entomologists and sanitary engineers to see how many are members of AMCA. Mosquito people being the gregarious types they are, we also had a good deal of contact with Navy and (yes) even Air Force types. Though *they* showed us no lists (spies, you know), we were able to make the same observation among them. We were a little disturbed, though, to note that quite a few of the entomologists, though they profess an interest in mosquitoes, are not listed as members of the Medical and Veterinary Entomology Section, Section D, of the Entomological Society of America, and we began to wonder if this might be also true of other AMCA'ers who are *not* members of the military reserves. Any of you AMCA'ers who are also ESA'ers ought to look into Section D. That's the mosquito control section . . . and we need all the membership we can muster, pals.

THE ANNUAL COURSE IN MILITARY ENTOMOLOGY SPONSORED BY THE THREE SERVICES AND GIVEN AT THE NAVAL MEDICAL CENTER IN BETHESDA, MARYLAND, was held during the two weeks of 10 through 22 July, with able assistance from ART LINDQUIST and his Department of Agriculture staff and *confréres*. Unfortunately, curtailment of travel funds reduced the class to about half the normal attendance but among those attending were LT. COL. OSMOND BRELAND, LT. COL. CARROLL SMITH, CAPT. DEAN GARRETT AND CAPT. CYRIL HODAPP and others, who lent their various talents to increasing the meatiness of the discussions. Among the "others" was HARVEY CRAWFORD, whom we have thus singled out not from rank consciousness but to point out that civilians in public health organizations are also welcomed very heartily to the course. AMCA'ers who are reservists and want the two weeks' duty or who are interested in learning more about this entomological specialty should get their applications in early for next year's course. Make a note, for when you're free to think about such things . . . after mosquito season's over!

WE WERE HAPPY, TOO, TO RUN ACROSS A BIT OF CORRESPONDENCE NOT MEANT FOR OUR EYES, FROM A LIEUTENANT GENERAL TO A LIEUTENANT COLONEL, BOTH KNOWN TO MANY AMCA'ERS. In part, Lt. General Leonard D. Heaton, the Surgeon General of the Army, said to Lt. Col. JOE WEBB, JR., that he was "particularly happy to be able to tell you that a prefix 'A' for your Military Occupational Specialty number in entomology has been authorized." Letter designations on MOS numbers indicate one's educational degrees and years of experience and are brought from D up to B on information supplied by the officer. Not so the "A" rating, however, which is reserved as an award for outstanding ability and accomplishment. STAN CARPENTER had been the only previous entomologist to be a recipient of this honor, we hear, and FRED WHITTIMORE received a like letter this time.

MAJOR MILTON B. FLEMINGS also received an accolade recently, from the New York newspapers, which commended Milt for his fine program of coöperation with civilian control agencies in the New York area. Milt, never one to let grass grow under his feet, did a lot of inspiring of community efforts in Japan and Korea, as we told you recently.

COL. RALPH BUNN has turned over his secretarial reins of the Armed Forces Pest Control Board to CAPT. DICK HOLWAY and expects to depart for a new assignment in Orlando, Florida. Washington's loss is Florida's gain, but Washington is recouping its loss by gaining Dick. This leaves Washington's gain to be California's loss but California, in turn, is gaining CDR. J. G. MCWILLIAMS, who left the NAMRU No. 3, in Cairo. So it's Nasser's loss, we guess, and he'll just have to make the best of it.

DR. WILLIAM BICKLEY, who was alternate as an AMCA representative at the Entomological

Congress in Vienna, took off with mixed sorrow and gladness when TED RALEY decided his duties during the mosquito season would have, after all, to come first. We promptly shifted the line of flattery we had intended for Ted to Bill and hope to get lots of notes about what went on there. Bill, like Ted, is a loyal and accommodating friend and AMCA'er and fertile source of much of our news and we expect to present you with the notes next time. Particularly since Ye Ed., DON COLLINS, is going too, and PRESIDENT JOBBINS and LESTER SMITH and ERNESTINE THURMAN. (Maybe this story will be too *big* for N & N!).

UNCLE HARRY STAGE was in Miami Beach in mid-June to attend the meetings of the American Medical Association and to *present a paper.* We always knew Harry was hiding something . . . calling everybody "Doctor." Dr. Stage said he sure wished he could see all his Florida friends but he just couldn't. We bet he's going to Vienna, too!

DR. AND MRS. FRED C. BISHOPP RECENTLY RETURNED TO THEIR HOME IN FLORIDA from an air-trip around the world. Two and a half months were spent in New Delhi, India, where Dr. Fred assisted in the U. S. Department of Agriculture's exhibits at the World Agricultural Fair. He had charge of the booth dealing with insecticides, fungicides, herbicides, anti-biotics and hormones. (We hope that the inclusion of the last two in the list of pesticides is not a Trend!) En route home, short stops were made in Athens, Tehran, Karachi, Calcutta, Singapore, Saigon, Hong Kong, Tokyo and Honolulu. Conferences with public health officials on various problems, particularly entomological and veterinary ones, took some of the time away from sightseeing, but made a nice balance, and it all sounds like a mighty fine trip. And one we're mighty glad Dr. and Mrs. B. could make. Welcome home! (Their address for the next few moments will be again 3823 E. River Drive, Fort Meyers, Florida.)

WE KNOW IT'S REALLY A BUSTLING AMERICAN CITY BUT TO US HONOLULU JUST SOUNDS AS ROMANTIC AND EXOTIC AS ALL GET OUT. So it is with some envy that we report that DR. GLEN HAAS has accepted a new appointment to the Health Department in our new state, where he will be a colleague of PAT NAKAGAWA and many AMCA'ers. He will work on plague problems, the life cycles of fleas and research on hosts and he won't forget about mosquitoes with all this, we hope.

RUSS FONTAINE took one look at once-glamorous but now quite prosaic California and turned right around and headed back to ICA. His next assignment will cover South and Central Americas (which ought to be about enough for even Russ' energies) and he will probably headquarter in Lima, Peru, but may decide on Brazil. In any case it means fluency in two languages, which if he didn't already have from his Caribbean days, he's now busily acquiring along with much else in cram sessions in Washington, D. C.

OTHERS WHO ARE MOVING AROUND INCLUDE W. J. BUCHANAN and CAPT. H. R. BULLOCK. "Buck" has gone to the ICA-METC Training Course at Kingston, Jamaica, West Indies, where his address is "% American Consulate General" and Howard has gone from the Army Environmental Health Laboratory to the Department of Entomology, University of Maryland, College Park. BILL FROHNE has left the Arctic Health Research Center in Anchorage, Alaska, for some place where he is listed as "Dr. William C. Frohne, USOM, APO 319, New York, N. Y." Where's that, Bill? CAPT. WALLACE P. MURDOCH is coming back to the States from Japan. His new address will be Division of Biological Sciences, Department of Zoology and Entomology, University of Utah, Salt Lake City, where he will be with DON REES and LEWIS NIELSEN. (We have a special interest in the University of Utah ourself, this year, since our recently-wed daughter will be continuing her education there, if you'll pardon a personal note.)

TED RALEY SENDS US WONDERFULLY STIMULATING AND PROVOCATIVE NOTATIONS ABOUT PEOPLE which raise our curiosity to a high pitch but don't tell us much of a damb thing, really, and we sure wish you fellows that get around so much would let us know your bright, shiny new assignments. However, Ted's lists do give us some very satisfying news sometimes. For instance, welcome to new AMCA'ers MAURICE V. BROWN and EDWARD O. LEWIS and congratulations to Kings County (Calif.) MAD, which is now 100 percent in AMCA in supervision. Welcome, too, to HARVEY I. MAGY and LT. COL. BOB TRAUB and DON MURRAY (all of whom we had thought were AMCA'ers long ago) and to AL S. WATANABE of the Hawaiian Spray Equipment Co.; and to DR. ENRIQUE SANCHEZ PALOMERA, Jefe del Departamento Medico y de Prev. Social, of Mexico 1, Distrito Federal, a special *¡ Bien venido!*

THE CALIFORNIA MOSQUITO CONTROL ASSOCIATION has announced some mighty encouraging results which they have had with a new insecticide called Bayer 29493. This is an organophosphate put out by Chemagro and Farbenfabriken Bayer and for you non-chemical-engineering types like ourselves we looked up its real name and it's O,O-dimethyl O-[4-(methylthio)-*m*-tolyl] phosphorothioate. (whew!) In conjunction with C. M. GJULLIN, RALPH BARR AND LARRY LEWALLEN have been running tests with the stuff since early last year and they say the appearances are mi-i-i-ty good. Highly toxic to mosquitoes, relatively less

toxic to warmblooded animals, like us. They think it may be a major break-through in our quest for where-do-we-go-from-here.

GEORGE THOMPSON FIRST CAME TO OUR ATTENTION WHEN WE RAN ACROSS HIS SLOGAN, *"Remember the mosquito will bite the hands that breed it."* His fresh approach to mosquito control has been furnishing us with some very stimulating bits of knowledge ever since and recently George decided to test out the old light trap method of detection of mosquito populations versus biting rates. George writes, "The June outbreak [of *Psorophora confinnis*] provided an excellent study of the different methods in use by this District to determine and evaluate mosquito outbreaks, especially as our plane was not in operation during the entire period. Landing rate counts provided the first warning of the impending flight. . . . The 'Light Trap' was three days behind 'Landing Rate in detecting the flight. . . . Service requests were not made until after the flight was well established in residential areas." George also suggests that members of AMCA might be interested in receiving a weekly report put out by the U. S. Department of Agriculture. This report is called the Cooperative Economic Insect Report (and we find it very informative, too) and George says he's been getting a lot out of it and thinks other mosquito men ought to see it and contribute to it. The address is: Survey and Detection Operations, Plant Pest Control Division, Agricultural Research Service, United States Department of Agriculture, Washington 25, D. C. Incidentally, a highlight on last season's scare from aminotriazole on cranberries and the lurid magazine articles on fire ant control, one of George's constituents phoned in to say that his BHC dust had drifted into a chicken house a little and "should the chickens be killed and the eggs destroyed?"

THE SAME RECENT ISSUE OF THE BULLETIN OF THE ENTOMOLOGICAL SOCIETY OF AMERICA FROM WHICH WE GOT THE NAME OF BAYER 29493, has a fine article on entomology at the University of Maryland and it was interesting to note the many famous entomologists who have been associated there and especially to see names like F. C. BISHOPP, GEORGE S. LANGFORD, RUFUS VINCENT, JAMES R. FOSTER, AND WILLIAM BICKLEY; also LAWRENCE W. SMITH, JR., ROBERT A. BERRY, JR., AND JERRY MALLACK . . . AMCA'ers all. Also mentioned for his early mosquito surveys and publications was A. B. Gahan.

A WORK CONFERENCE ON SYSTEMIC INSECTICIDES FOR THE CONTROL OF INSECT PESTS AND PARASITES OF LIVESTOCK was held on 11 and 12 July at Purdue University, according to an announcement sent us by DR. ART LINDQUIST. We think it is both interesting and provocative that so much work is being done on this approach to control of insects affecting animals, particularly since mosquitoes affect animals and we're an animal.

AND WHILE WE'RE CALLING ATTENTION TO RELEVANT RESEARCH IN NEARBY FIELDS, we wonder if you saw the article by Dr. R. C. Von Borstel of Pavia, Italy, in a recent issue of *Science* (Vol. 131, No. 3403, p. 878). He comments on an article by E. F. KNIPLING on irradiation to induce sterility in insects, to point out that monogamy is not a necessary factor in obtaining control of breeding by the liberation of sterile male populations. This widens the possibilities (he says) and we hope he's right.

VMCA's *Skeeter* IN ITS USUAL GOOD SOLID WAY PUTS ITS FINGER ON A PROBLEM which is causing headaches to a good many mosquito control people these days. Entitled "Drainage Is No Better Than Its Outlet," the short column points out some facts that are well worth reprinting for areas where urbanization is galloping over the farmlands. "When farm land is sold for real estate development," says *Skeeter*, "immediately the drainage picture takes on a new look. Now there will be roof tops and paved surfaces where rainwater must run off. The old outlet ditches, canals, culverts and pipes which were adequate for carrying away the surplus water from the farm field no longer have sufficient capacity to carry the increased flow. Flooding will occur and as a result mosquito production will be increased." *Skeeter* goes on to add that even though housing projects and developments may have adequate drainage in their design they may dump the water into systems which cannot carry away the increase. Mosquito abatement people will be doing their counties and communities a service if they quote these warnings to their local planners before plans are "set" without them.

YOU MAY REMEMBER SOME TIME AGO WE KIDDINGLY NOTED THAT CHET ROBINSON has had his Alameda County's fly problem dumped into his lap, sort of. Well, he's been busy. He reports that local Boards of Supervisors issued proclamations designating May 23 to May 27 as Fly Abatement Week. The Oakland (Calif.) Scavenger Association placed tags on the handles of 45,000 garbage cans giving information on the places where flies breed and a check list to help the householder in looking around for his own pet ones. The newspapers gave excellent coverage and it was fine public relations as well as good abatement. Incidentally Dean P. Furman is on Chet's Board of Trustees.

BILL BICKLEY SENT US THE CITATION GIVEN IN THE PRESENTATION OF AN HONORARY DEGREE TO DR. R. E. SNODGRASS by the University of Maryland on June 4, 1960. Although Dr. Snodgrass is

not a member of AMCA, he is so widely and affectionately known to mosquito men everywhere that we want to quote a part of the long remarks. "In his remarkable career," it said, "he made unparalleled contributions to the knowledge of insect anatomy and morphology as an entomologist with the United States Department of Agriculture, and has continued active research and publication since his retirement in 1945. His superbly illustrated books, interpretive papers, and inspiring lectures have continued to influence the thinking of countless thousands of biologists. As a lecturer and counselor of advanced students at the University of Maryland for nearly 25 years, he played an important role in the intellectual and scientific development of many individuals. His talents as a lecturer have been sought by leading institutions. Learned societies in the United States and in six other countries have honored him for his scientific attainments."

GEORGE BURTON, WHO HAS BEEN WORKING ON FILARIASIS IN INDIA for ICA, has recently published several papers on the subject in the *Indian Journal of Malariology* and is expecting to have some color film strips on filariasis and elephantiasis reproduced by CDC. He's been working principally on the bionomics of *Mansonioides,* spending his time in Cochin, Kerala, with occasional visits to his office way up in Delhi. He plans to come back to the states soon, but hopes to stay with the filariasis work afterward. We'd like to see those film strips!

OUR ESTEEMED CONTEMPORARY, PEST CONTROL MAGAZINE, has recently sent out to mosquito men everywhere a form letter advertising that NOW they can have a *monthly* news source. We think this is pretty tricky and we advise our readers to have nothing to do with it. In fact, although we have been assured by our distinguished rival that they would not dream of competing with us and plan only to act as a supplement, *if* we find out any of our Constant Readers are sending in little squibs on the sly to *them* and not to *us*. . . . we warn you! Fur will fly. (We aren't appeased by PC's calling us "AMCA's own splendid quarterly," either!)

WE DISCOVER WITH CONSTERNATION THAT OUR FIRST PRESENTEE IN WHO'S WHO IN AMCA THIS MONTH hasn't appeared before this, though we had thought we had told you about him long ago. Well, fortunately he doesn't need us to tell you about him. He was born on April 8th, 1910, under the sign of Aries, of whom they say, "Since his temper sometimes varies, one should not provoke an Aries." (We know this couplet because *we* were born in early April, too, and it's been quoted often enough to *us*.) But the couplet doesn't even begin to fit in his case, for an unruffled and pleasant mien is his trademark, known to all. He was born in New Brunswick, New Jersey, according to *American Men of Science,* and received his BS from Rutgers in 1931. An MS followed in 1935, while he was Assistant at the New Jersey Agricultural Experiment Station, a position he held from 1934 to 1938. He was then Senior Medical Entomologist at the Gorgas Memorial Laboratory, in Panama, from 1938 to 43, and followed this by being Sanitarian with the USPHS-Pan-American Sanitary Bureau from 1943 to 1948. Since then he has been Research Specialist at his old Alma Mater, Rutgers. He's married (in 1941) and had four children when counted in 1955. He's a member of the American Association for the Advancement of Science, the Entomological Society of America, the Society of Tropical Medicine, the Royal Society of Tropical Medicine and Hygiene and President of AMCA. . . . DANIEL MANLEY JOBBINS!

OUR NEXT CONFRÉRE IS NO COMPATRIOT BUT LIVES IN GENEVA, SWITZERLAND, or as his return address says, 9 Avenue de Miremont, Geneva, Suisse. He's with WHO as Director of Environmental Sanitation, with offices in the Palais des Nations. Actually, he *is* a compatriot, though an ex-patriate, for he was born on 1 October 1914 in Huron, South Dakota, USA. He received his BS in entomology from Iowa State in 1934, his MS from the same college in 1935 and his PhD from the University of Illinois in 1940. His mosquito work got off to a flying start during the war, when he was with Malaria Control in War Areas, being assigned all over. . . . Texas, Maryland, Missouri and Georgia. If you don't know, this included about all the military training areas there were, in point of populations and areas; the Fourth Service Command (Atlanta, Georgia) alone served camps containing 60 percent of the Army. From there, Dick went to the Technical Development Laboratory in Savannah, remaining with them from their small beginning to their magnificent present, as chief of the Insecticide Section and Assistant Chief of the Biology Section. In 1954 and 1957 he was a consultant to WHO and in 1959 was assigned to that Organization for two years, which brings him to where he now is. *Who* he now is? Gosh, we told you . . . DICK FAY!

J. B. GAHAN comes by his interest in mosquitoes naturally but he was a long time gettting there, in a way. It all added up to a lot of experience, though those who wait for him to tell them about it, unprodded, will wait a long time. Kind of quiet, Jim is. He was born in Berwyn, Maryland, in 1909 and received a BS degree in entomology from the University of Maryland in 1930. (Berwyn is near College Park and was heavily populated by USDA research people way back in 1940, when we lived there, but we didn't realize it even had existed in 1909! Well, now Jim's put it on the map.) He went on to get his MS in 1932, also from Maryland, while he was employed by the Division of Fruit Insects to work on the control

of codling moth. In 1935 he switched to the Division of Control Investigations, working on leaf-feeding insects and remained with that Division until 1943. Still no mosquitoes, although in 1942 a lot of us used to help an odd character named WILSON, who was interested in such things, dip around for larvae in the Beltsville NARC pond. 1943, however, saw Jim picked up and rushed to Orlando where the exciting early work on DDT was being done and where Jim had a large hand in doing it for the next three years. Between 1948 and 1951, he participated in a co-operative study with the Navy in housefly control in Egypt, making many lasting friendships at NAMRU 3. Returning to Orlando, he became project leader in premises treatment. Jim's hobbies are photography and music, both of which are "contemplative" sorts of activities, requiring considerable skill.

WE TOLD YOU LAST TIME ABOUT ROBERT A. HEDEEN, who is the new manager of South Cook County Mosquito Abatement District. He is a Texas-size Texan, born in Ft. Worth in 1928. He graduated from high school in 1945 and entered the University of Texas, from which he graduated at the unusually early age of 19, but not before OSMOND BRELAND had started him on the right path toward an interest in mosquitoes. In 1949, at the age of 20, BOB received his MS in entomology and commenced work on a PhD. This was interrupted, however, by the Army, which called him to be a 2nd Lt. in 1951 and in 1952 he became a Regular Army type and was sent back to Texas to finish up the doctorate. In 1953, with the degree under his belt (or around his shoulders) and a silver bar shining there, too, he was sent to Europe to command a preventive medicine company. For a while, the company was in Orleans, and then he went with it to La Rochelle, on the western seacoast. Three years later he returned to be assigned (now as a Captain) to the Medical Field Service School at Ft. Sam Houston, in San Antonio. Bob is married, with two boys, 9 and 7, and his hobbies are hunting, fishing, photography and spelunking. (Must be *mighty big caves*!)

AS A FOOTNOTE, BOB SENDS US SOME INFO ON SOUTH COOK COUNTY which made our eyes bug out. The District is 340 square miles in area and includes over 1,000,000 people in the suburbs of Chicago. Their budget runs over a half million dollars a year and they employ about 30 people full time, with 8 to 10 more part-time. A few years ago the area was one big swamp. Now it is one big swamp with houses. But the days when a fixed wing aircraft can operate in that area are limited (as anyone who has flown into Midway or O'Hare can testify) and so they hope to get a helicopter next spring. Bob says its a mighty big challenge which he and HERB HERMS and Brice Jones are meeting with (they hope) courage and (we know) resourcefulness, not always winning but always ready for a new try. He says it makes him feel very humble and grateful to his trustees and associates and with his determination we know he'll succeed well. We wish him luck.

## ALL AMCA MEMBERS

Last summer you received a memorandum from the Program Chairmen of the California Mosquito Control Association and the American Mosquito Control Association which constituted the Call for Titles of Papers to be read at the Annual Meeting. Please refer again to this memorandum, and if you plan to submit a title, note that the deadline is November 1, 1960.

Also, look over the other enclosures that came with that memorandum, and act now to make your hotel and other reservations.

# REVIEWS AND ABSTRACTS

HELEN LOUISE DURKEE

*Aëdes aegypti* (L.) The Yellow Fever Mosquito. Its Life History, Bionomics and Structure. By Sir S. Rickard Christophers. London and New York: Cambridge University Press, pp. xii + 739 (86 plates), 1960, $14.50. The most vexing problem of the culicidologist today is the enormous literature which must be comprehended before adequate new research can be undertaken. There are probably over 25,000 more or less important books, articles and pamphlets which have been devoted to the study of mosquitoes and the rate of production of such verbiage appears to be rapidly increasing. Probably 90 percent or more of what is written on the subject today contains little that is really new but represents confirmation or even rediscovery of previously published ideas. There is an all too prevalent attitude that it is easier to get a needed answer from experimentation than from published literature. This may occasionally result in a really new approach to a problem but, in the vast majority of cases, leads to duplication of previous works which as often as not were more thoroughly done. It is for this reason that comprehensive synthetic works are extremely valuable to the culicidologist. The last decade has been especially fruitful in this regard. The publication of Bates' *Natural History of Mosquitoes* in 1949 was an important step toward the synthesis of biological information on mosquitoes. The publication in 1951 of Muirhead-Thomson's *Mosquito Behavior in Relation to Malaria Transmission and Control in the Tropics* was an important step in the synthesis of information on the behavior of mosquitoes. The *Synoptic Catalogue of Mosquitoes of the World* by Stone, Knight and Starcke in 1959 was an important synthesis for the taxonomist. The last major gap, that of anatomy and morphology has been filled by Sir Christophers' book. Culicidologists are indeed in an enviable position. The work of synthesizing the literature is by no means completed, as a matter of fact it has hardly begun; these four books, however, form a good basic library for the novitiate and an invaluable set of references for the experienced research worker.

The present volume is first and foremost a study of the anatomy and morphology of mosquitoes. This is an area which has required review for many years, the standard references being the very old studies of Nuttal, Shipley, Imms and the review by Howard, Dyar and Knab. Last year Snodgrass contributed importantly to this field by his publication *The Anatomical Life of the Mosquito* which, however, is much less detailed than the present work, as well as having a more restricted subject of inquiry. Christophers' volume is the most comprehensive work on the structure of mosquitoes which has yet been published.

At first sight the work appears to be a compilation of what is known concerning *Aedes aegypti*. The references appear to number about 2,500; the number cannot be estimated with accuracy because they are scattered throughout the book at the end of each chapter which causes a good deal of duplication although such duplications are noted. The references would be much more useful, at least to this reviewer, if they were combined and placed at the end of the text. The latest references noted are dated 1958 but there are few of more recent vintage than 1955. In reading the text one is frequently impressed with the amount of work which has been done since that time.

Upon looking over the volume more closely one finds that it is much more than just a compilation of the literature. It consists, to a surprising extent, of new and unpublished information. Apparently Sir Christophers found many lacunae in knowledge of this species and tried systematically to fill in the details. The over-all result is a monograph, not limited, incidentally, to *Aedes aegypti*, containing a vast amount of previously unpublished information and constituting the only modern synthesis of work on the structure of mosquitoes.

The book is arranged in 31 chapters, each with its own list of references. The first five chapters constitute an introduction followed by three chapters on eggs, six on larvae, two on pupae and 15 on imagines.

The five chapter introduction is devoted to historical, systematic, ecological and medical aspects of *Aedes aegypti* and ends with a chapter on technique. This section is unevenly done. It contains a charming account of the evolution of common names of mosquitoes and a valuable survey of early writings concerning these insects. It also gives a more or less detailed account of the names which have been used for *Aedes aegypti* which could well have been omitted. There is a section on the identification of the species which would be more at home in a manual of identification than in the present work. There is a consideration of the geographical diversity and climatic requirements of the species which suggest having been written by a person more at home in the laboratory than in the field. There are short treatises on sex mosaics, fossil mosquitoes and parasites, which have little to do with *Aedes aegypti* although they may be useful, especially the last of the three. The section on predators is less complete and, surprisingly enough, fails to mention *Gambusia affinis* although the genus is mentioned. The chapter on medical aspects detracts from the quality of the book ("Japanese B. —and St. Louis encephalitis have also been considered possibly mosquito-borne (Marks, 1954)")

and would better have been omitted. The section on control is sketchy, outdated, and occasionally inaccurate ("An analogue of DDT, namely dieldrin . . ."); the section on repellents fails to mention diethyl-toluamide. The chapter on technique will be read avidly by the novitiate and expert alike since everyone seeks better ways of doing things. It contains a great deal of material on equipment and methods for rearing, mounting, dissecting and even sectioning mosquitoes, as well as various other kinds of techniques.

The three chapters on eggs are devoted to structure and biology, hatching and embryology. The anatomical discussions contain much new material as do the sections on size, growth changes, specific gravity, volume, and surface area of eggs. These sections were apparently finished before the recent works of Horsfall and his students were published and the section on waterproofing contains no reference to the work of Beckel. In this section as well as in the rest of the book Sir Christophers shows a weakness in knowledge of American works as Americans customarily have for English works or as either usually has for publications in other languages. The chapter on embryology seems to be the first detailed study of the embryology of mosquitoes which has been published; it applies to autogenous *Culex pipiens* rather than *Aedes aegypti*. In this, as in other sections of the book it is unfortunate that drawings are labelled with abbreviations since in most cases there is adequate space for the complete name of each structure.

The six chapters on larvae give detailed accounts of the morphology and anatomy of larvae and a consideration of instar differences. There are extensive accounts of the mouth parts, nervous system and tracheal system as well as the more familiar material. There is included a chapter on ecology and one on growth of larvae. Here, as elsewhere, the emphasis is on structure; function is less extensively considered. The two chapters on pupae concern anatomy and physical characteristics and contain a small amount on behavior.

The 15 chapters on the imago include one on physical characteristics, two on external anatomy and five on internal anatomy. Of the other seven chapters there are two on feeding and others on mating and oviposition, flight, special senses, environment and longevity, and physiological miscellany. Most of this work is written from an anatomical or grossly descriptive point of view. Again one notices the advances which have been made in study of the female reproductive system, humoral mechanisms and other topics since this work was written. There is no reference to the work of Boettiger and Furshpan on the mechanism of insect flight nor is there reference to Pringle's 1957 book on the subject.

Although the reviewer cannot qualify as an authority on the morphology of mosquitoes, many of Sir Christophers' interpretations appear to be doubtful. Much of the recent work in this field has been omitted completely. There is, for example, no mention of the studies of Cook or DuPorte of the morphology of larvae. Similarly, the newer interpretation of the adult thorax by Cook is not mentioned. These morphological problems appear to be handled with a greater amount of awareness in the recent monograph by Snodgrass.

The taxonomic practices used in this work also leave much to be desired. There are references to *Culex sollicitans, Culex nemorosus,* and to the "genera" *Lutzia, Mucidus, Lestiocampa* (*Goeldia*), and *"Taeniorhynchus"* (several times). The members of the *Culex pipiens* complex are given as *C. pipiens, C. fatigans, C. quinquefasciatus, C. pipiens* var. *pallens,* and *C. molestus.* It would appear that the time has come to discontinue using not only *Taeniorhynchus* but also *Megarhinus* and *Theobaldia.*

The criticisms of this work offered by the reviewer should not be taken as deprecation. In a work of this magnitude it is inevitable that there will be some faults. The book should be judged for what it is, the most extensive account of the structure of mosquitoes which has yet been published. It will be invaluable to all culicidologists, no matter what their interests, and will stimulate much new work to fill in the gaps which Sir Christophers has brought to life. The book is a fine monument to a lifetime of industry by one of our most eminent co-workers.—A. Ralph Barr, California State Department of Public Health.

STUDIES ON THE *Culex pipiens* GROUP OF JAPAN. 5. Morphological studies on the Nagasaki *molestus.* By Kamura, T. Endemic Dis. Bul. (Nagasaki Univ.) 1(2):176–185. 1959. 31 refs. Eng. summary.

In order to clear the morphological differences between Nagasaki *molestus* and Isahaya *pallens* and also Saporo *pallens* and Taihoku *fatigans,* examinations were made on the larval characters, Cell/Stem values of wing vein II of adults, and characters of genitalia of both sexes. Nagasaki *molestus* refers to *Culex pipiens molestus* found in old wells in Nagasaki city (Omori *et al.* 1955, Kamura 1959); Isahaya *pallens* to *C. p. pallens* widely and most commonly distributed in Nagasaki area; Sapporo *pallens* to the *pallens* sent from Sapporo, Hokkaido, northernmost part of Japan; Taihoku *fatigans* to the *fatigans* from Taihoku, Formosa.

The results of examinations are summarized as follows:

(1) In the branching of hair No. 1 of larval abdominal seg. III and IV and in the number of pecten teeth: Nagasaki *molestus* is similar to Sapporo *pallens* but considerably differs from Isahaya *pallens* and Taihoku *fatigans.*

(2) Between the means of Cell/Stem values of wing vein II of Nagasaki *molestus* and the other three strains, significant differences are found in both sexes, but the ranges of individual variations overlap widely with Sapporo *pallens* and Isahaya *pallens* or a little with *fatigans.*

(3) The number of hairs on post-genital plate and insula of female hypopygium is nearly the

same in the four strains, while the number of hairs on ninth tergite is peculiar in order of affinity, differing markedly in means in the number between Nagasaki *molestus* and Sapporo *pallens*. The ranges of individual variation, however, overlap rather widely with each other among the four strains.

(4) Nagasaki *molestus* clearly differs not only from *fatigans* but also from Isahaya *pallens* in that the DV/D values of male genitalia are extremely small, and the tip of the dorsal arm of the phallasome is flatly cut off and the ventral arm is narrowest and shortest, reaching only about the middle of the width of the dorsal arm. The *molestus* differs roughly from Sapporo *pallens* because in the latter strain the DV/D value is larger, the tip of the dorsal arm is rather swollen toward the middle of the cut off tip and the ventral arm is wider and its tip is rather longer.—Author's summary.

SUPPLEMENTS TO THE FINDINGS ON THE SUSCEPTIBILITY OF JAPANESE MOSQUITOES TO *Wuchereria bancrofti*. 2. On the susceptibility of *Anopheles hyrcanus sinensis* and *Culex tritaeniorhynchus*. By Fujisaki, T. Endemic Dis. Bul. (Nagasaki Univ.) 1(3):278–287. 1959. 26 refs. Eng. summary.

Studies on the susceptibility of *A. hyrcanus sinensis* and *Culex tritaeniorhynchus* to *Wuchereria bancrofti* were carried out from 1955 to 1957. These mosquitoes are feeding in the fields and drains in the fields and are widely distributed but not so abundant in the filariasis endemic districts in Western Kyushu, being hilly or rather rocky in topography.

The results of experimental infections with these mosquito species are summarized as follows:

(1) Within the body of *A. h. sinensis*, filaria larvae are killed mostly in 1b stage or in a very much earlier substage of the 1st stage. A very high percentage of these killed are chitinized. A small number of larvae reach the II stage but can scarcely reach the III stage. Throughout the experiments, on the 15th day after the infective meal, only one out of 339 females was found harboring 3 active IIc larvae of a substage just prior to the 2nd ecdysis.

The above results coincide well with those obtained by Mochizuki (1911) in Fukuoka, Kyushu, but differ considerably from those of Yamada (1927). The latter confirmed in Tokyo that larvae could reach maturity in 3 out of 16 infected females. The fact that filaria larvae cannot reach maturity in this mosquito in Kyushu suggests that the mosquito is not important in nature in the transmission of filariasis, at least in Kyushu, the most serious endemic district of the disease in Japan.

(2) Within the body of *Culex tritaeniorhynchus* many filaria larvae can reach 1d substage or a stage just before the 1st ecdysis when many of them are killed, but some can reach II stage and a few of them reach maturity. It is of interest that none of the larvae killed in the younger larval stage are chitinized. The percentage of matured larvae found in 128 females (the author) 20 females (Yamada, 1927) and 59 females (Mochizuki, 1911) are 4.7, 9.8, and 9.4 percent respectively. Thus the mosquito species is proved to have a low susceptibility but is rather zoophilus in feeding habits; and, consequently, it appears that the mosquito is of little importance in the transmission of filariasis in Japan.—Author's summary.

SOME NOTES ON MOSQUITOES COLLECTED ON FREDERIK HENDRIK ISLAND, (NETHERLANDS NEW GUINEA). By Assem, J. van den. Trop. geogr. Med. (Netherlands) 11(2):140–146. 1959. Twenty-five species of mosquitoes were collected in a two-week period (during the wet season) on this small island, about half the size of the Netherlands. Species collected were:

1. *Aedes funereus* (Theo.). Adults. Females biting.
2. *Aedes kochi* (Donitz). Adults. Females biting. Larvae.
3. *Aedes wallacei* (Edw.). Adults. Females biting.
4. *Aedes* (*Finlaya*) *sp. nov.* Discovered by Dr. E. N. Marks in *wallacei* material; to be described by her.
5. *Aedomyia catastucta* (Knab). Larvae.
6. *Anopheles b. bancrofti* (Giles). Blood-fed females. Larvae.
7. *Anopheles farauti* (Lav.). Stages not given.
8. *Culex annulirostris* (Skuse). Adults. Females biting. Larvae.
9. *Culex bitaeniorhynchus* (Giles). Larvae.
10. *Culex pullus* (Theo.). Larvae.
11. *Culex* (*Culiciomyia*) sp. Probably new species. Larvae.
12. *Culex fraudatrix* (Theo.). Adult female, bred from pupa, could not be positively identified because of lack of male.
13. *Ficalbia elegans* (Taylor). Larvae. Adults bred.
14. *Ficalbia metallica* (Leic.). Larvae and pupae. Adults bred.
15. *Ficalbia minima* (Theo.). Larvae.
16. *Hodgesia spoliata* (Edw.). Female biting.
17. *Mansonia bonnewepsterae* (v. d. Assem). Females biting.
18. *Mansonia ochracea* (Theo.). Female biting.
19. *Mansonia papuensis* (Taylor). Adults. Females biting.
20. *Mansonia uniformis* (Theo.). Adults. Females biting. Larvae.
21. *Mansonia xanthogaster* (Edw.). Females biting.
22. *Tripteroides quasiornata* (Taylor). Female biting.
23. *Uranotaenia albescens* (Taylor). Larvae.
24. *Uranotaenia papua* (Brug). Larvae.
25. *Anopheles amictus hilli*. Identified by author but not collected by him. Stages not given.

The author points out that this list does not represent the total number of species occurring on the island, nor does it indicate the changes that occur during the dry season. He discusses in some detail the habits and habitats of many of the species, and he devotes several paragraphs to a consideration of the almost total lack of mosquito-borne diseases. *Mansonia uniformis,* a vector of *Wuchereria bancrofti,* is present in numbers, but filariasis is unknown on the island; and *Anopheles bancrofti* and *A. farauti* are present and potential vectors of the parasite, but malaria is ALMOST NON-EXISTENT. —H. L. Trembley Durkee.

CHANGING CONCEPT OF *Wuchereria bancrofti* TRANSMISSION IN NETHERLANDS NEW GUINEA. By Rook, H. de, and Dijk, W. J. O. M. van. Trop. geogr. Med. 11(1):57–60. 1959. 12 refs. There is enough evidence to incriminate the anophelines of the *punctulatus* group—*A. farauti, A. punctulatus,* and *A. koliensis*—as vectors of nocturnal *W. bancrofti* filariasis in Melanesia. Of these, *A. farauti* is probably the most important vector. In New Guinea *A. bancrofti* and possibly *A. karwari,* also play an additional part in the transmission.

The suggestion that anophelines play the major —if not the only—part in filariasis transmission in New Guinea has been found to need revision, as in Netherlands New Guinea natural infection with full-grown bancroftian larvae has been encountered in 5 non-anopheline species, while experimental infection with full development of the larvae into the infective stage was observed in 2 other species.

Taking into account the hospitability, spread, abundance, longevity, biting habits, and the distance between human dwellings and the breeding sites of these non-anopheline vectors, evidence is growing that some of these species really compete with anophelines in efficiency to transmit *W. bancrofti* filariasis in New Guinea.

It will be clear that all this influences filariasis control. Indoor spraying with residual insecticides, primarily directed against malaria, would also automatically eradicate anopheline-borne filariasis. However, *Mansonia uniformis* which in some places bites rather often out-of-doors, and DDT-resistant *C. fatigans* require other measures—Author's summary and excerpt from text.

GRAU DE SUSCEPTIBILIDADE DO *Anopheles* (*Nyssorhynchus*) *darlingi* AO DDT EM DUAS LOCALIDADES DO ESTADO DE MINAS GERAIS (BRASIL). By Rachou, R. G., Moura Lima, M., Machado Leal, J. Rev. Bras. Malariol. D. Trop. 11(1):67–68. 1959. In March-April, 1958, the susceptibility of *Anopheles darlingi* to DDT was tested in two localities of the State of Minas Gerais, Pedra Maria da Cruz and Fazenda Curral das Varas, both in the Municipio of Januária, in the São Francisco valley. The Busvine and Nash technique was followed. The mosquitoes exposed to the insecticide were caught with human bait. In both localities *Anopheles darlingi* revealed high susceptibility; the L. C. 50 in Pedra Maria da Cruz was 0.26 percent ±0.01, and in Fazenda Curral das Varas 0.37 percent ±0.03. The houses in both localities were sprayed at least three times when the tests were made.—Authors' summary.

CYTOLOGICAL AND ECOLOGICAL RESEARCHES ON BRAZILIAN ANOPHELIDS. By Schreiber, G. and Guedes, A. S. Rev. Bras. Malariol. D. Trop. 11 (1):97–98. 1959. (In English) This is a brief but stimulating account by the authors (of the University of Minas Gerais, and Departmento Nacional de Endemias Rurais, Belo Horizonte, Brasil) of research completed and in progress at Belo Horizonte.

The caryotypes have been determined of *A. argyritarsis, A. strodei, A. darlingi, A. noroestensis,* and *A. homunculus.* Salivary gland chromosome maps of the same species are being prepared. The map of *A. argyritarsis* is completed as well as the map of the X chromosome of *A. strodei.* These two species have been studied with a view to establishing a possible relationship between their ecological distribution and chromosome polymorphism. There have been variations in behavior of some female *A. darlingi* in areas treated with insecticides. Larvae have been reared from these females and their chromosome structure studied. These investigations are being made in an effort to establish the relation between chromosome polymorphism and insecticide resistance, or variation in ecological distribution and behavior after insecticide application. In addition, a special study is being made of *A. strodei's* egg shell-structure and chromosome polymorphism.—H. L. T. D.

THE EFFECT OF TEMPERATURE AND ILLUMINATION ON MATING OF *Culex pipiens pipiens* L. AND *C. p. fatigans* WIED. By Parker, Anne C. M., and Rozeboom, L. E. Amer. Jour. trop. Med. Hyg. 9(3):331–335. 1960. 10 tables. Mating experiments with several strains of *C. p. pipiens* and *C. p. fatigans* at different temperatures showed that *fatigans* was more active at all temperatures, but was less inhibited than *pipiens* at the highest temperature. With decreasing intensity of illumination, *fatigans* began swarming sooner than did *pipiens,* but ceased shortly after complete darkness was attained, whereas *pipiens* continued to swarm in the dark.

It is concluded that *fatigans* does not exhibit a specific temperature adaptation for mating, but that the higher insemination rates at all temperatures were the result of an inherent sexual aggressiveness. However, such differential activity could be a means of limiting the establishment of *pipiens* in warmer areas, where it would have to compete with the more active *fatigans.* Furthermore, these differences in response to temperature and changes in illumination could be a mechanism for keeping the population segregated in some areas where they coexist.—Authors' summary.

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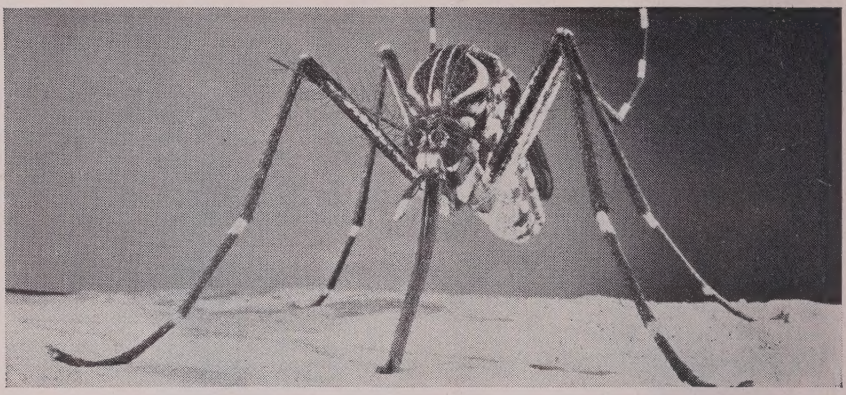

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